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Survey of Plants for Antimalarial Activity*

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INTRODUCTION

There are numerous reports in the literature concerning the presence of principles in plants which appeared to possess activity against malarial infections or "fevers." As a part of a recent search for new antimalarial drugs, a survey of plants was made in order to determine whether new natural products could be found which would have useful antimalarial activity.

The first phase of this program required a chemical extraction procedure and a biological assay method which could be applied conveniently to hundreds of extracts of various plant samples. This phase of the program consisted of "screening-tests" which were designed to show which plants contained active principles. It was desirable that this combined chemical and biological screening-test be as dependable as possible in order that a plant which contains active principles would not be found "inactive" and discarded. By this test, those plants which showed the presence of active principles were determined and reserved for further study. In some cases, attempts were made to isolate and characterize the principles as pure compounds in order that further pharmacological studies could be made.

This report describes the data which have been secured from the "screening-tests" on the plants for antimalarial activity. The data are summarized in Table 1 and represent the results of the tests on about six hundred

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different plants. In many cases, several samples or parts of a plant were extracted and tested. These plants represent one hundred and twenty-three families of the *Phanerogamæ* and three families of the *Cryptogamæ*.

BOTANICAL ASPECTS OF THE TESTS

The botanical aspects of the project on testing plants for antimalarial activity were handled by Mr. J. Monachino, under the guidance of Mr. B. A. Krukoff at the New York Botanical Garden. The plants tested were selected largely on the basis of references in the available literature on the uses of plants as antimalarials, febrifuges, etc. In most cases, when plants showed positive results, attempts were made to obtain samples of related species. Species of related genera were tested for orientation purposes.

For a great majority of the samples of plants used in these studies, the identity was established by accompanying herbarium material. The numbers which were assigned to the samples (Table 1) were also assigned to the botanical vouchers.

The botanical work in this project, involving the identification of many hundreds of plants from various parts of the world, could not have been possible without the resources of the New York Botanical Garden, particularly its vast collection of preserved plants and its extensive botanical library. These resources, as well as office space and other facilities, were made freely available to Messrs. Krukoff and Monachino by Dr. William J. Robbins, the Director of the New York Botanical Garden.

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CHEMICAL ASPECTS OF THE TESTS

The three extraction procedures, which are indicated in Table 1 by the appropriate number, were devised so that general procedures, which would be applicable to a great variety of plant samples, could be used. Methanol

or ethanol extraction of moistened plant material or direct water extraction were employed. For all extractions, an aqueous concentrate or extract (water soln., Table 1) was always submitted for biological tests. For many plants, the chemical constituents, such as alkaloids, bitter principles, etc., which are present, can be removed from a neutral or weakly alkaline aqueous solution by continuous extraction with chloroform. In those cases where such constituents are present, such a chloroform extraction achieves a considerable purification and concentration of the constituents. Biological tests on the solutions of such chloroform extractives are frequently more satisfactory than those on the original aqueous concentrates. This continuous chloroform extraction step was always used on a portion of the aqueous extract, and the yields of the chloroform residues expressed in percentage, as based on the ground plant material, are recorded in Table 1.

Procedure 1.—A sample of the finely ground plant material, usually weighing about 200 g., was moistened with water and exhaustively extracted with methanol in a Soxhlet apparatus for about twenty-four to forty-eight hours. The extract was then concentrated *in vacuo* to a volume of about 100–200 ml., or until all the methanol had been removed. At this step of the process, there was often a precipitate in the concentrate. Any precipitate which was present was removed by filtration, dried and tested biologically. In only one case, that of *Cornus florida*, did this precipitate show appreciable activity. The aqueous concentrate or filtrate was then divided into two equal portions. The amount of the solids in one portion of the aqueous concentrate was determined with 5 ml. of solution which was evaporated to dryness. When the aqueous concentrate had a pH below 5–5.5, sodium bicarbonate was added until the pH of the solution was 5.5–6.0, and then the solution was submitted for biological test. The other portion of the aqueous solution was made alkaline with sodium bicarbonate and extracted continuously with chloroform until all extractable material had been removed. The chloroform extraction required eight to twenty-four hours. The chloroform extraction was done in this way in order to remove small amounts of alkaloids and other compounds from the rather large amounts of extraneous matter present in the aqueous extracts. The chloroform extract was then concentrated to dryness *in vacuo*. The residue was weighed and dissolved when possible in the minimum amount of 95% ethanol (preferred concentration, 300 mg./ml.). When the chloroform residue was insoluble in ethanol, it was suspended in an aqueous solution of gum acacia. The ethanol solutions or the gum acacia suspensions were then submitted for biological tests.

Procedure 2.—The method was the same as Procedure 1, except that 95% ethanol and used in place of methanol.

Procedure 3.—The ground plant material was extracted with water in a beaker at a temperature of 50–60° C. with mechanical stirring. After an

hour, the mixture was centrifuged and the plant residue was extracted again with fresh water. This water extraction was repeated once or twice more. The solutions were combined and concentrated *in vacuo* to a volume of 100–200 cc. This extract was divided into two portions and treated as in Procedure 1.

Pharmacological Aspects of the Tests

The experimental malarial infections were produced in healthy seven-day-old chicks and five- to six-day-old ducklings according to the experimental procedure described by Seeler, Malanga and Pierson.* Trophozoite induced *Plasmodium gallinaceum* infections were established in white Leghorn chicks by intrajugular inoculation with 200,000,000 parasitized red cells per kilogram (a, Table 1). The sporozoite infection was produced by inoculating each chick with a quantity of sporozoite suspension approximately equivalent to one mosquito per chick (b, Table 1). The trophozoite induced infections of *Plasmodium cathemerium* were produced in white Pekin ducklings by inoculation with 500,000,000 parasitized red cells per kilogram (c, Table 1), and those of *Plasmodium lophurae* in ducklings were established in a similar manner (d, Table 1).

Drug treatment of each experimental infection was begun immediately after inoculation and continued for three days in the *Plasmodium gallinaceum* sporozoite test and five days in the other tests. Drugs were administered subcutaneously (s.c., Table 1) and/or orally (p.o., Table 1), depending on concentration, solubility, etc. Thin blood smears were taken at the peak of the infections and the number of parasitized red cells per 10,000 red cells was determined. The antimalarial activity of a drug was estimated by comparison of the parasite counts with those of untreated birds and of birds treated with quinine (excellent activity given by 40 mg./kg. p.o. in tests a and d, and 80 mg./kg. p.o. in test c) or sulfadiazine (excellent activity given by 0.4% in the diet). Relative activity of an extract was classified as inactive (0), slight (+ , moderate (++), good (+++), or excellent (++++).

COMMENTS ON THE TESTS

The extracts of quite a number of different plants were found to show antimalarial activity and to deserve some degree of further study and testing. The extracts of many plants were found to be biologically inactive at the dose levels employed. Whenever possible, a given extract was tested at the highest tolerated level so that any possible activity might be observed even though the dose level might be a toxic one. For extracts which contain active principles at toxic levels, further tests could be made

* A. O. Seeler, C. Malanga and J. Pierson, Proc. Soc. Exp. Biol. & Med., **59**: 291, 1945.

in order to determine whether the activity and toxicity were related or dissociable.

Extracts of leaves, roots or stems of *Dichroa febrifuga* showed significant suppressive activity against *Plasmodium gallinaceum* in the chick.

The bark of *Cornus florida* was found to yield a water-insoluble product which appeared to show specific activity against *Plasmodium cathemerium*. This crude product completely suppressed the schizonts of *Plasmodium cathemerium* in the duck when it was administered with the diet at a concentration of 2%. This product had little or no effect against *Plasmodium lophurae* in the duck or against *Plasmodium gallinaceum* in the chick.

Sixty-eight different plants of several genera of *Simaroubaceae* were tested and many of them were retested several times. The distribution of active principles possessing antimalarial activity seemed to be rather broad within this family of plants. However, the suppressive activity of typical extracts against *Plasmodium gallinaceum* in the chick was generally associated with toxic properties so that the therapeutic usefulness of such principles in man was questionable. Noteworthy plants of *Simaroubaceae* which were studied included *Castela tortuosa*, *Simaba cedron*, and *Simarouba amara*.

An interesting discovery was the finding that several plants of the *Amaryllidaceae* possessed principles which showed varying degrees of activity in the suppressive test and in the prophylactic test against *Plasmodium gallinaceum* in the chick. Extracts of forty-four different plants of several genera of *Amaryllidaceae* were examined. Particularly interesting plants were *Hymenocallis caribaea* and *Cooperia pedunculata*. The activity of these extracts of *Amaryllidaceae* appeared to be associated with the alkaloidal fractions. The low yields of these alkaloidal fractions in the bulbs of these plants and the erratic character of some of the results hampered a more definitive exploration of these active principles.

Other plants, such as *Schultesia lisianthoides*, *Gentiana* sp. ("Corpus huait"), *Remijia peruviana*, *Eryngium foetidum*, *Datisca glomerata*, *Aristolochia* sp. ("Dululu"), *Cissampelos pareira*, *Croton* sp. ("copalchi"), also showed varying degrees of activity as may be seen by perusal of Table 1.

None of the plants appeared to contain active principles which offered unqualified therapeutic promise for malarial infections in man. The projection of the results of treatment of experimental malarial infections in poultry to the clinical treatment of the malarial infections of man is a difficult one and requires extensive intermediate experimentation. However, further research on these active principles, which might include isolation, structure determination, syntheses, and synthetic modifications, together with extensive pharmacological investigations, might lead to useful drugs for parasitic infections.

TABLE 1. *Summary of the Actitives of Various Plant Extracts.*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			PHANEROGAMAE				
			ACANTHACEAE				
Adhatoda vasica	16359	Branches & lvs.	200	1	3.85	o at 6320 p.o.[a] o at 3160 p.o.[b]	o at 328 p.o.[a] o at 328 p.o.[b]
Barleria prionitis	18544	Entire	200	1	1.56	o at 8505 p.o.[a]	o at 464 s.c.[a]
Blechum brownei	18893	Entire	154	1	1.09	o at 8320 p.o.[a]	o at 280 s.c.[a]
Lepidagthis alopecuroidea	17925	Entire	240	1	1.64	o at 4180 p.p.[a]	o at 400 s.c.[a]
Ruellia tuberosa	17163	Entire	256	1	0.11	o at 8410 p.o.[a]	o at 29 p.o.[a]
Ruellia tuberosa	18387	Entire	543	1	0.38	o at 13590 p.o.[c] o at 13590 p.o.[d]	o at 128 s.c.[c] o at 128 s.c.[d]
			AMARANTHACEAE				
Centrostachys indica	17484	Roots	196	1	0.14	o at 4800 p.o.[a]	o at 43 p.o.[a]
Iresine sp.	15967	Entire	200	1	0.21	o at 4280 p.o.[a] o at 4280 p.o.[b]	o at 440 p.o.[a] o at 440 p.o.[b]
Pfaffia lanata	16337	Roots	156	1	0.37	+ at 5940 p.o.[a]	o at 184 p.o.[a]
?	16080	Stems & lvs.	119	1	3.13	o at 1840 p.o.[a] o at 1840 p.o.[b]	o at 80 s.c.[a] o at 80 s.c.[b]
			AMARYLLIDACEAE				
Agave sp.	18917	Bulbs	220	1	2.36	o at 6560 p.o.[b] o at 4000 p.o.[a]	o at 500 s.c.[b] o at 400 s.c.[a]
Amaryllis belladonna	17712	Bulbs	315	1	1.13	+++ at 544 p.o.[a]	o at 22.7 s.c.[a]
Amaryllis belladonna	17712	Bulbs	469	1	1.31	o at 530 p.o.[b]	o at 20 p.o.[b]
Bomarea martiana	18643	Roots	142	1	1.34	o at 3300 p.o.[a,b]	o at 300 p.o.[a] o at 150 p.o.[b]
Buphane disticha	17128	Bulbs	419 (dried)	1	2.13	+ at 2280 p.o.[b] o at 1140 p.o.[a]	o at 212 p.o.[b] o at 106 p.o.[a]
Callipsyche sp.	19092	Bulbs	545	1	0.40	o at 400 p.o.[a] o at 1000 p.o.[b]	o at 75 p.o.[a,b]
Chlidanthus fragrans	18417	Bulbs	490	1	0.44	+++ at 1000 p.o.[a] + at 500 p.o.[a] o at 500 p.o.[b]	o at 20 s.c.[a] o at 50 s.c.[b]
Cooperia pedunculata	15654	Bulbs	113	1	0.11	o at 416 p.o.[a]	+++ at 3.2 s.c.[a]
Cooperia pedunculata	17650	Bulbs	306	1	0.33	o at 335 s.c.[b] +++ at 670 p.o.[a]	+ at 66.5 p.o.[b] + at 266 p.o.[a]
Crinum americanum	16848	Bulbs	660	1	0.40	++ at 1000 p.o.[a] ++++ at 500 p.o.[b]	o at 150 p.o.[a] o at 76 p.o.[b]
Crinum americanum	16848	Bulbs	403	1	0.39	o at 341 p.o.[d]	o at 25 s.c.[d]
Crinum erubescens	18899	Bulbs	297	1	0.51	o at 250 s.c.[a,b]	o at 25 s.c.[a,b]
Crinum grandiflorum	18517	Bulbs	317	1	0.33	+ at 1230 p.o.[b]	+ at 50 s.c.[b]
Crinum longifolium	18765	Bulbs	481	1	1.03	o at 250 p.o.[a] o at 1000 p.o.[b]	+ at 30 s.c.[a] o at 30 s.c.[b]
Crinum moorei	17788	Bulbs	253 (dried)	1	2.06	o at 750 p.o.[b]	o at 50 s.c.[b]
Crinum sp.	18762	Bulbs	301	1	0.63	+ at 125 p.o.[a] + at 500 p.o.[b]	+ at 15 s.c.[a] o at 10 s.c.[b]
Furcraea tuberosa	15073	Roots	135	1	0.92	o at 2000 p.o.[b]	o at 154 s.c.[b]
Habranthus texanus	17456	Bulbs	300	1	0.31	+ at 742 p.o.[a]	+ at 50 p.o.[a]
Habranthus texanus	18442	Bulbs	517	1	0.39	+ at 1320 p.o.[a] o at 1320 p.o.[b]	o at 80 s.c.[a,b]
Hippeastrum cf. flammigerum	18656	Bulbs	176	1	0.39	o at 400 p.o.[a] ++ at 650 p.o.[b]	+ at 52 s.c.[a] o at 52 s.c.[b]
Hippeastrum puniceum	18289	Bulbs	530	1	0.19	++ at 142 p.o.[b] ++ at 71 p.o.[a]	o at 25 s.c.[b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			AMARYLLIDACEAE—*continued*				
Hippeastrum puniceum	18688	Bulbs	513	1	0.26	+++ at 200 p.o.[b]	++ at 25 s.c.[a] o at 20 s.c.[b]
Hippeastrum vittatum	17636	Bulbs	360	1	0.14	+ at 534 p.o.[a]	++ at 80 p.o.[a]
Hippeastrum sp.	18952	Bulbs	134	1	1.33	o at 200 p.o.[a,b]	o at 20 s.c.[a,b]
Hippeastrum sp.	18722	Bulbs	409	1	0.19	+++ at 400 p.o.[b]	o at 50 s.c.[b] ++ at 50 s.c.[a]
Hymenocallis americana	18640	Bulbs	166	1	0.58	+++ at 250 p.o.[b]	o at 25 s.c.[b]
Hymenocallis americana	18871	Bulbs	426	1	0.63	++ at 500 p.o.[b]	++ at 50 p.o.[b]
Hymenocallis calathina	16826	Bulbs	335	1	0.51	o at 562 p.o.[a] o at 450 p.o.[b]	+ at 102 p.o.[a] o at 51 p.o.[b]
Hymenocallis caribaea	16612	Bulbs	123	1		o at 90 p.o.[a] ++ at 360 p.o.[b]	
Hymenocallis caribaea	18330	Bulbs	200	1	1.39	+++ at 1000 p.o.[b]	o at 50 s.c.[b]
Hymenocallis caribaea	18566	Bulbs	550	1	0.14	+ at 500 p.o.[b] + at 300 p.o.[a]	o at 50 s.c.[b]
Hymenocallis caribaea	18511	Bulbs	643	1	0.43	o at 250 p.o.[b]	o at 20 s.c.[b]
Hymenocallis caribaea	18604	Bulbs	570	1	0.34	o at 100 p.o.[b]	o at 10 sc.[b]
Hymenocallis caribaea	18566	Bulbs	515	1	0.22	+ at 500 p.o.[b]	o at 25 s.c.[b]
Hymenocallis caribaea	18623	Bulbs	573	1	0.61	+ at 500 p.o.[b]	+ at 20 s.c.[b]
Hymenocallis caribaea	18789	Bulbs	497	1	0.65	+ at 250 p.o.[a,b]	+ at 20 s.c.[a,b]
Hymenocallis caymanensis	18379	Bulbs	563	1	0.20	o at 283 p.o.[a,b]	o at 15 s.c.[a] o at 20 s.c.[b]
Hymenocallis caymanensis	18379	Bulbs	518	1	0.42	o at 250 p.o.[b]	o at 10 s.c.[b]
Hymenocallis caymanensis	18919	Bulbs	580	1	0.42	+ at 100 s.c.[b]	o at 50 s.c.[b]
Hymenocallis coronaria	17195	Bulbs	230	1	0.66	+ at 200 p.o.[a] o at 200 p.o.[b]	o at 100 p.o.[a] ++ at 100 p.o.[b]
Hymenocallis galvestonensis	17403	Bulbs	311	1	0.46	++ at 389 p.o.[a] o at 500 p.o.[b]	+ at 25 s.c.[a] o at 25 s.c.[b]
Hymenocallis occidentalis	18439	Bulbs	528	1	0.31	o at 500 p.o.[b]	o at 10 s.c.[b]
Hymenocallis palmeri	18221	Bulbs	356	1	0.53	o at 280 p.o.[b]	o at 25 s.c.[b]
Hymenocallis rotata	16841	Bulbs	130	1	0.42	o at 805 p.o.[a]	o at 66 p.o.[a]
Hymenocallis sp.	15653	Bulbs	189	1	0.77	++ at 614 p.o.[a] + at 614 p.o.[b]	++ at 66 p.o.[a]
Hymenocallis sp.	16803	Bulbs	80	1	0.21	o at 4700 p.o.[a]	o at 72 p.o.[a]
Hymenocallis sp.	16847	Bulbs	620	1	0.57	+++ at 308 p.o.[a] o at 308 p.o.[b]	o at 80 p.o.[a,b]
Hymenocallis sp.	18627	Bulbs	486	1	0.90	++ at 1000 p.o.[a]	++ at 50 s.c.[a]
Hymenocallis sp.	18451	Bulbs	603	1	0.19	o at 188 p.o.[a] o at 300 p.o.[b]	o at 25 s.c.[a] o at 30 s.c.[b]
Hymenocallis sp.	18452	Bulbs	586	1	0.29	o at 9720 p.o.[a,b]	o at 20 s.c.[a] o at 25 s.c.[b]
Lycoris radiata	17940	Bulbs	170	1	0.49	++ at 515 p.o.[b] ++ at 500 p.o.[a]	o at 10 s.c.[b]
Manfreda variegata	17806	Entire	263	1	0.67	o at 3200 p.o.[b]	o at 125 s.c.[b]
Manfreda variegata	18759	Roots	438	1	0.32	o at 3030 p.o.[a,b]	o at 132 s.c.[a,b]
Manfreda virginica	15779	Bulbs	100	2	0.42	o at 4000 p.o.[a]	o at 160 s.c.[a]
Pancratium maritimum	18575	Bulbs	415	1	0.77	++ at 500 p.o.[b]	o at 25 s.c.[b] + at 25 s.c.[a]
Sprekelia formosissima	18766	Bulbs	305	1	0.51	o at 100 p.o.[a] + at 200 p.o.[b]	o at 12.5 s.c.[a,b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			AMARYLLIDACEAE—*continued*				
Stenomesson sp.	19093	Bulbs	357	1	1.33	o at 1000 p.o.[a] + at 1000 p.o.[b]	o at 100 p.o.[a] ++ at 100 p.o.[b]
Zephranthes atamasco	17860	Entire	339	1	0.57	++ at 204 p.o.[b]	o at 2.5 s.c.[b]
"Azucena"	18597	Bulbs	437	1	0.28	+ at 400 p.o.[a] + at 500 p.o.[b]	o at 50 s.c.[b] o at 25 s.c.[a]
"Azucena"	18576	Bulbs	217	1	0.77	o at 1000 p.o.[b]	o at 50 s.c.[b]
"Mañanita"	18577	Bulbs	228	1	0.48	o at 300 p.o.[b]	o at 50 s.c.[b]
			ANACARDIACEAE				
Mangifera indica	17300	Bark	171	1	0.08	o at 7820 p.o.[a]	
Schinus polygamus var. chilensis	16367	Branchlets & lvs.	200	1	1.68	+ at 8400 p.o.[a]	+ at 60 s.c.[a]
Shinus polygamus var. chilensis	18208	Branchlets & lvs.	390	1	17.55	o at 4320 p.o.[o,d]	o at 362 s.c.[o,d]
Sclerocarya caffra	18596	Bark	209	1	0.25	o at 8280 p.o.[a]	o at 80 s.c.[a]
			ANNONACEAE				
Annona foetida	17367	Inner bark	176	1	0.07	o at 1400 p.o.[a]	
Annona muricata	17815	Wood	177	1	0.32	o at 3675 p.o.[a]	o at 118 s.c.[a]
Cleistopholis patens	17779	Bark	206	1		o at 5330 p.o.[a]	
Rollinia rugulosa	16383	Bark	120	1	0.18	o at 2070 p.o.[a]	o at 16 s.c.[a]
Uvaria rufa	16061	?	200	1	0.62	o at 2880 p.o.[a,b]	o at 56 p.o.[a,b]
			APOCYNACEAE				
Alstonia constricta	17690	Roots	234	1	1.37	o at 4170 p.o.[a]	o at 645 p.o.[a]
Apocynum cannabinum	9736	Stems & lvs.	125	1	2.72	o at 3236 p.o.[a,b]	o at 284 p.o.[a,b]
Aspidosperma chakensis	16173	Bark	200	1	3.08	o at 1760 p.o.[a]	o at 300 p.o.[a]
Aspidosperma megalocarpon	17858	Bark	240	1	0.44	o at 5200 p.o.[a]	o at 230 s.c.[a]
Aspidosperma nitidum	16780	Bark	350	1	0.37	o at 3840 p.o.[a] o at 960 s.c.[a]	o at 90 s.c.[a]
Aspidosperma nitidum	18743	Bark	327	1	1.77	o at 1780 p.o.[a]	o at 115 s.c.[a]
Aspidosperma nitidum	16780	Bark	443	1	0.38	o at 5660 p.o.[d]	o at 182 s.c.[d]
Aspidosperma peroba	16096	Wood	200	1	1.54	o at 3760 p.o.[a]	o at 204 p.o.[a,b]
Aspidosperma polyneuron	17950	Bark	235	1	1.93	o at 2470 p.o.[a]	o at 50 s.c.[a]
Aspidosperma quebracho-blanco	16174	Branches & lvs.	159	1	1.71	o at 2080 p.o.[a] o at 520 p.o.[b]	o at 250 p.o.[a]
Aspidosperma quebracho-blanco	15741	Bark	200	1	1.92	o at 1100 p.o.[a]	o at 124 p.o.[a,b]
Aspidosperma quebracho-blanco	17552	Bark	116	1	1.29	o at 1800 p.o.[a]	o at 225 p.o.[a]
Aspidosperma sp.	16716	Bark	255	1	6.95	+ at 783 p.o.[a] o at 783 p.o.[b]	o at 1048 p.o.[a,b,d]
Aspidosperma sp.	16722	Bark	108	1	0.56	o at 2100 p.o.[a]	o at 232 p.o.[a] o at 116 p.o.[b]
Conopharyngia ventricosa	18706	Bark	220	1	1.14	o at 1800 p.o.[a]	o at 444 s.c.[a]
Geissospermum vellosii	16097	Wood	200	1	4.05	o at 2500 p.o.[a,b]	o at 324 p.o.[a] ++ at 324 p.o.[b]
Holarrhena antidysenterica	17037	Leaves	200	1	0.33	o at 7700 p.o.[a,b]	o at 41 p.o.[a] o at 82 p.o.[b]
Holarrhena febrifuga	17358	Roots	212	1	0.77	o at 1610 p.o.[a]	o at 400 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			APOCYNACEAE—*continued*				
Plumeria multiflora	17021	Bark	183	1	0.40	o at 4210 p.o.[a,b]	o at 26.5 p.o.[a,b]
Plumeria cf. rubra	17104	Roots	151	1	0.38	o at 2620 p.o.[a]	o at 18 s.c.[a]
Plumeria sucuuba	18053	Bark	209	1	0.25	o at 1820 p.o.[a]	o at 115 s.c.[a]
Rauwolfia heterophylla	17564	Entire	298	1	0.58	o at 2760 p.o.[a]	o at 412 p.o.[a]
Rauwolfia heterophylla	17564	Roots	440	1	0.94	o at 1540 p.o.[c] o at 1232 p.o.[d]	o at 20 s.c.[c] o at 10 s.c.[d]
Rauwolfia sandwicensis	17200	Roots	237	1	1.45	o at 560 p.o.[a]	o at 594 p.o.[a]
Rauwolfia sp.	17291	Tops & lvs.	62	1		o at 3840 p.o.[a]	
Tabernaemontana amygdalifolia	16206	?	200	1	5.98	o at 1460 p.o.[a,b]	+ at 248 p.o.[a] o at 248 p.o.[b]
Tabernaemontana amygdalifolia	17658	Stems	209	1	1.02	o at 3765 p.o.[a]	o at 600 p.o.[a]
Tabernaemontana citrifolia	17109	Bark	228	1	1.39	o at 997 p.o.[a]	o at 4380 p.o.[a]
Tabernaemontana heterophylla	18071	Roots	212	1	2.10	o at 2780 p.o.[a]	o at 223 s.c.[a]
Tabernaemontana oppositifolia	18821	Bark	150	1	2.47	o at 3400 p.o.[a]	o at 330 s.c.[a]
Thevetia ovata	17392	Fruits	260	1	0.27	o at 727 p.o.[a]	o at 28 p.o.[a]
Thevetia peruviana	17663	Fruits	217	1	0.55	o at 625 p.o.[a]	o at 110 p.o.[a]
Thevetia peruviana	18895	Bark	206	1	0.90	o at 5030 p.o.[a]	o at 20 s.c.[a]
Thevetia peruviana	17663	Fruit	417	1		o at 20 p.o.[d]	o at 1.0 s.c.[d]
Vallesia glabra	16311	Bark	185	1	1.40	o at 7200 p.o.[a] o at 3600 p.o.[b]	o at 1000 p.o.[a,b]
Vinca rosea	17425	Roots	200	1	1.56	++ at 4420 p.o.[a]	+ at 400 p.o.[a]
			AQUIFOLIACEAE				
Ilex opaca forma subintegra	16630	Bark	232	1	0.85	o at 2550 p.o.[a,b] o at 1275 p.o.[d]	o at 256 p.o.[a,b]
Nemopanthes mucronata	16909	Branches and lvs.	210	1	0.52	o at 3448[a] o at 5172[b]	o at 294 p.o.[a]
			ARALIACEAE				
Gilibertia arborea	17040	Branches & lvs.	186	1	0.21	o at 1320 p.o.[a,b]	o at 16 p.c.[a] o at 66 p.c.[b]
Hedera helix	9606	lvs.	108	1	0.60	o at 2680 p.o.[a] + at 1340 p.o.[b]	o at 64 p.o.[a]
Hedera helix	18371	Stems & lvs.	479	1	4.53	o at 2470 p.o.[c] o at 3705 p.o.[d]	o at 300 s.c.[c,d]
Hedera helix	17096	Entire	326	1	0.87	o at 6200 p.o.[c,d]	o at 285 s.c.[c,d]
			ARISTOLOCHIACEAE				
Aristolochia acuminata	18585	Roots	205	1	0.18	o at 396 p.o.[a]	o at 48 s.c.[a]
Aristolochia triangularis	17913	Stems	147	1	0.56	o at 2740 p.o.[a]	o at 147 s.c.[a]
Aristolochia trilobata	15636	Stems	402	1	0.46	o at 2390 p.o.[a] o at 4780 p.o.[c,d]	o at 300 s.c.[d] o at 150 s.c.[c]
Aristolochia sp. "Dululu"	17740	Roots	189	1	0.50	+ at 3470 p.o.[a]	o at 192 p.o.[a]
Aristolochia sp. "Dululu"	18701	Roots	200	1	1.32	+++ at 3100 p.o.[a]	o at 528 s.c.[a]
			ASCLEPIADACEAE				
Asclepias curassavica	9827	?	200	1	2.67	o at 4520 p.o.[a]	o at 130 p.o.[a]
Cryptolepis sp.	17738	Roots	153	1		o at 4860 p.o.[a]	

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
				AVICENNIACEAE			
Avicennia nitida	17536	Bark	150	1	0.17	0 at 2270 p.o.[a]	0 at 40 p.o.[a]
				BASELLACEAE			
Boussingaultia sp.	17820	Tubers	221	1	0.17	0 at 3120 p.o.[a]	0 at 70 s.c.[a]
				BERBERIDACEAE			
Berberis cf. ruscifolia	17011	Roots	200	1	2.14	0 at 1216 p.o.[a,b]	0 at 200 p.o.[a] 0 at 400 p.o.[b]
Berberis sp.	17069	Roots	108	1	4.39	0 at 1210 p.o.[a]	0 at 148 s.c.[a,b]
				BETULACEAE			
Betula papyrifera	17063	Bark	200	1	1.15	0 at 3150 p.o.[a]	0 at 288 p.o.[a,b]
				BIGNONIACEAE			
Newbouldia laevis	18867	Roots	200	1	0.75	0 at 5175 p.o.[a]	0 at 300 s.c.[a]
Tabebuia argentea	16201	Bark	500	2	3.54	0 at 6600 p.o.[a,b]	++ at 250 p.o.[a] 0 at 180 p.o.[b]
Tabebuia argentea	16830	Bark	186	1	0.71	0 at 9040 p.o.[a,b]	0 at 141 p.o.[a] 0 at 70 p.o.[b]
Tabebuia argentea	16830	Bark	441	1	1.35	0 at 13,620 p.o.[c] 0 at 20,430 p.o.[d]	0 at 225 s.c.[c,d]
Tabebuia ipe	15857	Bark	200	1	2.55	0 at 16,400 p.o.[a]	0 at 196 p.o.[a]
Tabebuia pallida	9744	Bark	163	1	0.85	0 at 14,800 p.o.[a] 0 at 7400 p.o[b]	0 at 36 p.o.[a,b]
Tabebuia sp.	18573	Stems & bark	200	1	1.05	0 at 3820 p.o.[a]	0 at 300 s.c.[a]
				BIXACEAE			
Bixa orellana	16851	Seeds	147	1	10.32	0 at 3913 p.o.[a,b]	0 at 388 p.o.[a,b,d]
Bixa orellana	18437	Seeds	411	1	0.55	0 at 8680 p.o.[c,d]	0 at 100 s.c.[c,d]
				BOMBACACEAE			
Adansonia digitata	17341	Bark	277	1	0.10	0 at 1650 p.o.[a]	0 at 60 p.o.[a]
Adansonia digitata	17341	Bark	406	1	0.31	0 at 1450 p.o.[d] 0 at 725 p.o.[c]	0 at 175 s.c.[d] 0 at 87 s.c.[c]
Bombax ellipticum	17525	Branches & lvs.	205	1	0.20	0 at 2900 p.o.[a]	0 at 73 p.o.[a]
Bombax ellipticum	17537	Branches & lvs.	134	1	0.18	0 at 1920 p.o.[a]	0 at 40 p.o.[a]
				BORAGINACEAE			
Borago officinalis	16642	Flowers	210	1	0.20	0 at 4460 p.o.[a] 0 at 8920 p.o.[b]	0 at 46 p.o.[a,b]
Cordia sp.?	15969	Bark	200	1	0.28	0 at 4630 p.o.[a]	0 at 304 p.o.[a]
Ehretia timifolia	17041	Bark	156	1	0.42	+ at 4180 p.o.[a] 0 at 4180 p.o.[b]	+ at 81 p.o.[a] 0 at 81 p.o.[b]
Ehretia tinifolia	18416	Bark	331	1	1.35	0 at 4380 p.o.[c,d]	+ at 50 s.c.[c]
Sebesten rickseckeri	16208	Branches	60	2+3	0.70	0 at 2000 p.o.[a,b]	0 at 100 s.c.[a]
Sebesten rickseckeri	16208	Leaves	193	1	0.02	0 at 4300 p.o.[a] 0 at 2860 p.o.[b]	0 at 100 p.o.[a] 0 at 52 p.o.[b]
Sebesten sebestena	16254	Branchlets & lvs.	125	1	1.37	0 at 1800 p.o.[a,b]	0 at 56 p.o.[a,b]
				BROMELIACEAE			
Bromelia karatas	18594	Infructescence	215	1	3.89	0 at 5160 p.o.[a]	0 at 928 s.c.[a]
				BRUNELLIACEAE			
Brunellia comocladifolia	16284	Branches	65	1		0 at 1220 p.o.[a,b]	0 at 500 p.o.[a,b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			BURSERACEAE				
Elaphrium grandifolium	15957	Bark	94	1	—	o at 3320 p.o.[a]	
Elaphrium microphyllum	15415	Bark	200	1	0.20	o at 2860 p.o.[a,b,d]	o at 53 p.o.[a]
Elaphrium simaruba	16165	Stems	190	2+3	0.35	o at 650 s.c.[a]	
Elaphrium simaruba	16126	Fruits	177	1	0.30	o at 4400 p.o.[a] + at 4400 p.o.[b]	o at 64 s.c.[a]
Elaphrium simaruba	17295	Branches & lvs.	228	1	0.21	o at 2360 p.o.[a,b]	o at 110 s.c.[b]
			CALYCANTHACEAE				
Calycanthus floridus	17134	Fruits	43	1		o at 2890 p.o.[a]	
			CANELLACEAE				
Canella winterana	16169	Branches	200	1	0.24	o at 400 p.o.[a,b]	o at 80 p.o.[a] +++ at 80 p.o.[b]
Canella winterana	16016	Roots	252	1	0.39		o at 80 p.o.[b]
Canella winterana	15640	Bark	404	1	0.61		o at 160 p.o.[b]
Canella winterana	17202	Roots	4214	1	0.56	o at 3420 p.o.[a,b]	o at 306 p.o.[a] o at 612 p.o.[b]
Canella winterana	17202	Leaves	528	1	4.14	o at 2920 p.o.[a,b] o at 730 s.c.[a,b]	o at 916 p.o.[a,b] o at 458 s.c.[a,b]
Canella winterana	17202	Stems	200	1	0.15	+ at 900 p.o.[a] ++++ at 900 p o.[b]	o at 40 s.c.[a] +++ at 80 s.c.[b]
Canella winterana	18140	Bark	275	1	0.52	o at 4680 p.o.[a] o at 7020 p.o.[b]	o at 337 s.c.[b]
Canella winterana	18140	Branches	220	1	0.82	o at 2120 p.o.[a,b]	o at 90 s.c.[a] o at 180 s.c[b]
Canella winterana	18140	Roots	220	1	0.63	o at 1000 p.o.[a,b]	o at 173 c.s.[a] ++ at 173 p.o.[b]
Canella winterana	18140	Stems	200	1	0.46	o at 1050 p.o.[a,b]	o at 495 s.c.[a] o at 660 s.c.[b]
Canella winterana	17202	Roots	218	1	0.20	o at 688 p.o.[b]	+++ at 52 p.o.[b]
Capsicodendron dinisii	18689	Roots	193	1	0.61	o at 2600 p.o.[a] + at 3900 p.o.[b]	o at 184 s.c.[a] o at 362 s.c.[b]
Capsicodendron dinisii	18198	Bark	205	1	0.13	o at 1810 p.o.[a,b]	o at 335 s.c.[b]
Warburgia ugandensis	18516	Inner bark	245	1	0.36	o at 2070 p.o.[a] o at 1035 p.o[b]	o at 150 s.c.[a,b]
			CAPPARIDACEAE				
Capparis spinosa	17812	Roots	236	1	0.12	o at 3420 p.o.[a] o at 1140 p.o.[b]	
Cleome gynandra	16982	Roots	238	1	0.03	o at 612 p.o.[a]	
Polanisia trachysperma	16922	Entire	190	1	2.06	o at 4228 p.o.[a] o at 6342 p.o.[b]	o at 712 p.o.[a,b]
Polanisia viscosa	17480	Roots	98	1		o at 2560 p.o.[a]	
			CARICACEAE				
Carica papaya	17521	Flowers	201	1	0.40	o at 3720 p.o.[a]	o at 166 p.o[a]
			CAPRIFOLIACEAE				
Symphoricarpos albus	17922	Roots	203	1	0.77	o at 3560 p.o.[a]	o at 296 s.c.[a]
Triosteum perfoliatum	15846	Roots	200	1	1.44	o at 9240 p.o.[a] + at 4620 p.o.[b]	o at 116 p.o.[a,b]
			CARYOPHYLLACEAE				
Silene capensis	17759	Entire	190	1	1.02	o at 5625 p.o.[a]	o at 440 s.c.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			CELASTRACEAE				
Maytenus boaria	17116	Roots	231	1	0.13	o at 286 s.c.[a]	o at 50 s.c.[a]
			CHENOPODIACEAE				
Eurotia lanata	16019	Branchlets & lvs.	154	1	0.67	o at 5760 p.o.[a]	o at 104 p.o.[a,b]
			CHLORANTHACEAE				
Hedyosmum arborescens	18269	Bark	109	1	3.47	o at 2260 p.o.[a]	o at 756 s.c.[a]
			CISTACEAE				
Lechea villosa	16078	Upper stems & fruits	300	1	0.07	o at 1180 p.o.[a] + at 1180 p.o.[b]	o at 40 p.o.[a,b]
Lechea villosa	16078	Upper stems & fruits	107	1	0.84	o at 675 p.o.[b] o at 337 p.o.[a]	o at 100 s.c.[b]
			CNEORACEAE				
Cneorum pulverulentum	19080	Roots	208	1	2.78	o at 1900 p.o.[a]	o at 390 s.c.[a]
			COMBRETACEAE				
Anogeissus latifolia	16860	Bark	245	1	0.29	o at 2605 p.o.[a] o at 7815 p.o.[b]	o at 100 p.o.[a] o at 160 p.o.[b]
Conocarpus erecta	15907	Bark	1800	2, 3, 4	—	o at 1200 p.o.[a,b]	o at 400 p.o.[a,b]
Conocarpus erecta	15122	Bark	430	1	0.70	o at 6660 p.o.[c] o at 9990 p.o.[d]	o at 400 s.c.[c] o at 200 s.c.[d]
			COMMELINACEAE				
Commelina communis	16005	Entire	106	1	2.37	o at 3640 p.o.[a] o at 1820 p.o.[b]	o at 60 p.o.[a,b]
			COMPOSITAE				
Acanthospermum xanthoides	17581	Entire	253	1	1.25	o at 7340 p.o.[a]	o at 740 p.o.[a]
Achillea millefolium	18175	Tops	210	1	1.16	o at 5060 p.o.[a]	+ at 525 s.c.[a]
Achyrocline flaccida	16226	Entire	200	1	0.87	o at 4520 p.o.[a,b]	o at 20 p.o.[a] o at 52 p.o.[b]
Achyrocline satureioides	16340	Entire	126	1	3.82	o at 1840 p.o.[a]	o at 38 p.o.[a]
Ambrosia artemesiaefolia	16833	Entire	225	1	4.69	o at 3607 p.o.[a] o at 7214 p.o.[b]	o at 616 p.o.[a,b,d]
Artemisia gnaphalodes	18060	Tops	200	1	1.15	o at 5120 p.o.[a]	o at 450 s.c.[a]
Artemisia tridentata	2R1643	Upper	200	1	2.80	o at 4892 p.o.[a]	o at 322 p.o.[a]
Artemisia tridentata	17058	Upper	200	1	2.43	o at 3890 p.o.[a,b,d]	o at 278 p.o.[a,b,d]
Baccharis genistelloides	19189	Entire	200	1	0.61	o at 9800 p.o.[a]	o at 425 s.c.[a]
Balsamorhiza sagittata	16453	Roots	200	1	0.25	o at 6778 p.o.[a]	o at 98 p.o.[a]
Bidens pilosa	16425	Tops with flowers	180	1	5.18	o at 6800 p.o.[a] o at 3400 p.o.[b]	o at 152 p.o.[a]
Calea urticifolia	17857	Branches & lvs.	279	1	0.47	o at 5880 p.o.[a]	o at 200 s.c.[a]
Calea zacatechichi	15972	Entire	130	1	1.54	o at 3280 p.o.[a,b]	o at 140 p.o.[a,b]
Calea sp. ?	16024	Entire	127	1	3.97	o at 2140 p.o.[a,b]	o at 104 p.o.[a,b]
Carthamus lanatus	17921	Roots	225	1	0.42	o at 1850 p.o.[a]	o at 150 s.c.[a]
Centaurea calcitrapa	16828	Upper	200	1	2.08	+ at 4832 p.o.[a] o at 9660 p.o.[b]	+ at 112 p.o.[a] o at 224 p.o.[b]
Centaurea cyanus	16517	Flowers	155	1	0.60	o at 1676 p.o.[a]	o at 166 p.o.[a]
Cephalophora aromatica	17119	Entire	130	1	0.79	o at 8476 p.o.[a,b]	o at 67 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			COMPOSITAE—*continued*				
Chrysactina mexicana	16123	Upper	144	1	0.69	o at 1720 p.o.[a,b]	o at 152 p.o.[a] o at 76 p.o.[b]
Chuguiraga insignis	16308	?	169	1	10.28	o at 3400 p.o.[a,b]	o at 388 p.o.[a,b]
Chuguiraga leucoxylon	16620	Leaves	200	1	0.26	o at 4507 p.o.[a,b]	o at 81 p.o.[a,b]
Chuguiraga leucoxylon	16620	Roots	206	1	0.16	o at 3670 p.o.[a]	o at 90 p.o.[a]
Conyza filaginoides	16130	Entire	166	1	3.40	o at 1860 p.o.[a]	o at 88 p.o.[a] ++ at 88 p.o.[b]
Conyza lyrata	17747	Entire	198	1	0.28	o at 1225 p.o.[a]	o at 77 s.c.[a]
Cnicus benedictus	16514	Upper	185	1	0.26	o at 5200 p.o.[a]	o at 54 p.o.[a]
Culcitium rufescens	16307	?	184	1	5.80	o at 4040 p.o.[a]	o at 172 p.o.[a]
Elephantopus nudatus	17475	Entire	190	1	0.66	o at 5860 p.o.[a]	o at 312 p.o.[a]
Emilia sonchifolia	17721	Entire	210	1	2.09	o at 3960 p.o.[a]	o at 268 s.c.[a] o at 268 p.o.[a]
Eupatorium capillifolium	15908a	Tops with flowers	200	1	—	o at 3160 p.o.[a,b]	
Eupatorium ligustrinum	17818	Stems & lvs.	199	1	3.63	+ at 4480 p.o.[a]	o at 45 s.c.[a]
Eupatorium rotundifolium	17548	Entire	210	1	0.86	o at 6060 p.o.[a]	+ at 450 p.o.[a]
Eupatorium verbenaefolium	17234	Entire	213	1	0.57	o at 4440 p.o.[a,b]	o at 141 p.o.[a,b]
Eupatorium verbenaefolium	17440	Roots	310	1	0.45	o at 8320 p.o.[a]	o at 266 p.o.[a]
Faujasia flexuosa	18545	Stems & lvs.	200	1	0.88	o at 6795 p.o.[a]	o at 440 sc.[a]
Flotovia excelsa	17832	Stems & lvs.	209	1	0.89	o at 4920 p.o.[a]	o at 360 s.c.[a]
Gnaphalium cheiranthifolium	16619	Entire	195	1	0.21	o at 3041 p.o.[a] o at 4561 p.o.[b]	o at 83 p.o.[a]
Gnaphalium sp.	16124 16624	Entire	136	1	2.19	o at 3860 p.o.[a]	o at 312 p.o.[a]
Helenium tenuifolium	15213	Stems & flowers	200	1	2.94	o at 4600 p.o.[a]	o at 940 p.o.[a]
Helichrysum parviflorum	17797	Entire	228	1	1.06	o at 4440 p.o.[a]	o at 384 s.c.[a]
Heterothalamus alienus	17643	Branches & lvs.	191	1	1.08	o at 6780 p.o.[a]	o at 504 p.o.[a]
Iva frutescens	17017	Entire	200	1	0.76	o at 3065 p.o.[a,b]	o at 400 p.o.[a] o at 200 p.o.[b]
Matricaria chamomilla	16652	Flowers	102	1	3.24	o at 2760 p.o.[a,b]	o at 472 p.o.[a,b,d]
Matricaria globifera	17762	Entire	212	1	1.06	o at 6405 p.o.[a]	o at 510 p.o.[a]
Mikania glomerata	16322	Stems & lvs.	200	1	0.57	o at 6880 p.o.[a]	o at 136 p.o.[a]
Neurolaena lobata	16028	Entire	280	2	0.37	o at 2500 p.o.[a] o at 1660 p.o.[b]	o at 200 p.o.[a]
Neurolaena lobata	16608	Entire	412	1	0.85	o at 2820 p.o.[c] o at 5640 p.o.[d]	o at 284 s.c.[c] o at 142 s.c.[d]
Parthenium hysterophorus	16081	Entire	135	1	4.18	o at 1684 p.o.[a] o at 3368 p.o.[b]	o at 244 p.o.[a,b]
Pectis febrifuga	16877	Entire	195	1	3.52	o at 2670 p.o.[a,b]	+ at 328 p.o.[a] o at 328 p.o.[b]
Piqueria trinervia	16075	Stems	220	2	3.04	o at 3000 p.o.[a,b]	o at 3600 p.o.[a]
Pluchea odorata	17031	Entire	138	1	0.56	o at 1520 p.o.[a,b]	o at 58 s.c.[a] o at 116 s.c.[b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			COMPOSITAE—*continued*				
Porophyllum gracile	16376	Entire	200	1	0.22	0 at 4920 p.o.[a]	0 at 20 s.c.[a]
Spilanthes ocymifolia	16026	Entire	100	2	0.53	0 at 3500 p.o.[a,b]	
Stevia satureiaefolia	17794	Entire	252	1	0.50	0 at 3780 p.o.[a]	0 at 150 s.c.[a]
Tessaria integrifolia	18945	Roots	203	1	2.14	0 at 4665 p.o.[a]	0 at 612 s.c.[a]
Tithonia rotundifolia	16106	Entire	99	1	1.15	0 at 2000 p.o.[a,b]	0 at 36 p.o.[a,b]
Verbesina occidentalis	16993	Roots	208	1	0.14	0 at 3000 p.o.[a,b]	
Vernonia cinerea	18086	Entire	99	1	0.91	0 at 1170 p.o.[a]	0 at 160 s.c.[a]
Vernonia noveboracensis	16880	Roots	200	1	1.31	0 at 1336 p.o.[a,b]	0 at 172 p.o.[a,b]
Xanthium spinosum	17488	Stems & lvs.	267	1	0.60	0 at 10,580 p.o.[a]	0 at 380 p.o.[a]
Zinnia pumila	18353	Entire	201	1	0.14	0 at 4200 p.o.[a]	0 at 296 s.c.[a]
			CONNARACEAE				
Rourea glabra	18873	Roots	201	1	0.10	0 at 1820 p.o.[a]	0 at 57 s.c.[a]
			CONVOLVULACEAE				
Evolvulus arizonicus	15875	Entire	410	1	2.56	0 at 10,480 p.o.[c,d]	0 at 250 s.c.[c]
Ipomoea coccinea	18531	Stems, lvs., fruits	213	1	0.93	0 at 5880 p.o.[a]	0 at 210 s.c.[a]
			CORNACEAE				
Cornus amomum	16986	Bark	91	1		0 at 6180 p.o.[a,b,d]	
Cornus canadensis	17064	Entire	218	1	0.39	0 at 5040 p.o.[a,b]	0 at 100 p.o.[a,b]
Cornus florida	16518	Bark	170	1	0.67	0 at 8198 p.o.[a]	0 at 436 p.o.[a]
Cornus florida	18394	Bark				0 at 1460 p.o.[c,d]	0 at 212 s.c.[c,d]
Garrya fremontii	15434	Roots	190	2+3		0 at 2400 p.o.[a,b]	0 at 240 s.c.[a]
Garrya goldmanii	15512	Roots	358	1	1.62	0 at 4080 p.o.[c] 0 at 6120 p.o.[d]	0 at 227 s.c.[c,d]
			CROSSOSOMATACEAE				
Crossosoma bigelovii	18846	Roots	200	1	1.44	0 at 386 p.o.[a]	0 at 20 s.c.[a]
Crossosoma bigelovii	18846	Stems	200	1	0.52	0 at 1450 p.o.[a]	0 at 36 s.c.[a]
			CUCURBITACEAE				
Ecballium elaterium	18600	Entire	211	1	3.12	0 at 2710 p.o.[a]	0 at 156 s.c.[a]
Momordica charantia	15816	Upper	189	1	0.97	0 at 3440 p.o.[a,b]	0 at 42 s.c.[a]
Momordica charantia	9939	Upper	435	1	1.06	0 at 2370 p.o.[c,d]	0 at 496 s.c.[c]
			CYPERACEAE				
Cyperus odoratus	18863	Roots	162	1	0.41	0 at 2840 p.o.[a]	0 at 172 s.c.[a]
			DATISCACEAE				
Datisca glomerata	18191	Roots	200	1	0.12	0 at 1340 p.o.[a]	+++ at 5 s.c.[a]
Datisca glomerata	18191	Stems lvs., flowers	202	1	0.54	0 at 3980 p.o.[a]	0 at 10 s.c.[a]
			DICHAPETALACEAE				
Dichapetalum cymosa	15292	Entire	220	1	0.19	0 at 1020 p.o.[a]	0 at 80 p.o.[a]
			DIOSCOREACEAE				
Dioscorea glauca	17065	Roots	208	1	0.20	0 at 2240 p.o.[a,b]	0 at 60 p.o.[a,b]
Dioscorea glauca	17065	Roots	422	1	0.98	0 at 11,580 p.o.[d] 0 at 8685 p.o.[c]	0 at 294 s.c.[c,d]
Rajania hastata	18862	Roots	194	1	1.48	0 at 7120 p.o.[a]	0 at 480 s.c.[a]
			EBENACEAE				
Diospyros poeppigiana	16313	Bark	243	1	0.05	0 at 2100 p.o.[a,b]	0 at 16.5 p.o.[a,b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
				ELAEOCARPACEAE			
Aristotelia moqui	18880	Bark & stems	201	1	0.21	0 at 4120 p.o.[a]	0 at 110 s.c.[a]
				ERICACEAE			
Oxydendrum arboreum	16525	Leaves	200	1	1.65	0 at 6794 p.o.[a]	0 at 117 p.o.[a]
Oxydendrum arboreum	16698	Bark	175	1	1.25	0 at 6371 p.o.[a,b]	0 at 296 p.o.[a,b]
				EUPHORBIACEAE			
Croton californicus	15442	Branchlets & lvs.	200	1	0.32	0 at 3160 p.o.[a]	+ at 32 s.c.[a]
Croton capitatus	16122	Twigs	350	2	0.16	0 at 1400 p.o.[a,b]	+ at 300 s.c.[a]
Croton capitatus	17290	Upper	192	1	0.16	0 at 2060 p.o.[a]	0 at 52 p.o.[a]
Croton capitatus	16894	Entire	235	1	0.38	0 at 3640 p.o.[a]	0 at 234 p.o.[a]
Croton ciliato-glandulosus	15067	?	57	1	4.50	0 at 1060 p.o.[a]	0 at 44 p.o.[a]
Croton glabellus	16191	Bark	200	1	1.93	0 at 2740 p.o.[a,b]	0 at 240 p.o.[a,b]
Croton aff. niveus	17286	Bark	525	1	0.32	0 at 8740 p.o.[c] 0 at 13,110 p.o.[d]	0 at 330 s.c.[c] 0 at 165 s.c.[d]
Croton cf. reflexifolius	15393	Bark	200	1	4.39	0 at 3868 p.o.[a]	0 at 2930 p.o.[a]
Croton cf. reflexifolius	17565	Bark	290	1	0.18	0 at 4890 p.o.[a]	0 at 100 p.o.[a]
Croton cf. reflexifolius	15393	Bark	190	2	2.84	0 at 1000 p.o.[a] 0 at 1240 p.o.[b]	0 at 1000 p.o.[a,b]
Croton tiglium	9747	Leaves	192	1	0.97	0 at 5640 p.o.[a,b]	0 at 160 p.o.[a,b]
Croton tonduzii	16825	Bark	150	1		0 at 832 p.o.[a,b]	0 at 1492 p.o.[a,b]
Croton sp. "Copalchi"	16131	Bark	157	1	2.72	0 at 2560 p.o.[a,b]	0 at 176 p.o.[a] ++ at 176 p.o.[b]
Croton sp.	16247	Bark	118	1		0 at 625 p.o.[a,d]	
Croton sp.	16625	Bark & stems	158	1		0 at 2430 p.o.[a]	
Phyllanthus carolinensis	16633	Entire	68	1		0 at 1650 p.o.[a,d] 0 at 3300 p.o.[b]	
Phyllanthus niruri	16240	Entire	90	1	2.96	0 at 5760 p.o.[a]	0 at 704 p.o.[a]
Phyllanthus niruri	17110	Entire	430	1	2.25	0 at 4650 p.o.[c] 0 at 9300 p.o.[d]	0 at 220 s.c.[c] 0 at 110 s.c.[d]
Phyllanthus pentandrus	17374	Entire	222	1	0.34	0 at 7320 p.o.[a]	0 at 168 p.o.[a]
				FAGACEAE			
Castanea dentata	16691	Roots	190	1	0.18	0 at 3738 p.o.[a]	0 at 89 p.o.[a]
Castanea pumila	16635	Bark	242	1	0.21	0 at 2890 p.o.[a,b] 0 at 400 p.o.[d]	0 at 87 p.o.[a]
Quercus falcata	17589	Bark	301	1	0.42	0 at 7560 p.o.[a]	0 at 282 p.o.[a]
				FLACOURTIACEAE			
Casearia cf. sylvestris	18726	Stems	200	1	1.32	0 at 4880 p.o.[a]	0 at 580 s.c.[a]
Hasseltia sp.	17621	Bark	230	1	0.20	0 at 2120 p.o.[a]	0 at 80 p.o.[a]
				FUMARIACEAE			
Fumaria officinalis	17563	Stems & lvs.	230	1	0.56	0 at 6360 p.o.[a]	0 at 384 p.o.[a]
				GENTIANACEAE			
Chelonanthus alatus	17089	Entire	137	1	1.39	0 at 3330 p.o.[a]	0 at 48 s.c.[a,b] 0 at 24 s.c.[d]
Chironia humilis var. wilmsii	17827	Entire	258	1	5.43	0 at 5060 p.o.[a]	0 at 175 s.c.[a]
Erythraea beyrichii	16623	Entire	270	1	1.45	0 at 14,082 p.o.[a] 0 at 10,562 p.o.[b]	0 at 752 p.o.[a,b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			GENTIANACEAE—*continued*				
Erythraea centaurium	17005	Entire	208	1	0.92	o at 8920 p.o.[a]	o at 208 p.o.[a]
Erythraea chilensis	16382	Entire	130	1	1.79	o at 5580 p.o.[a]	o at 166 p.o.[a]
Erythraea texense	16677	Entire	100	1	1.86	o at 5880 p.o.[a]	o at 372 p.o.[a]
Erythraea venusta	16928	Entire	150	1	1.40	+ at 8404 p.o.[a] o at 8404 p.o.[b]	o at 540 p.o.[a]
Eustoma russellianum	16813	Upper part & roots	110	1	1.80	o at 3580 p.o.[a,b]	o at 152 p.o.[a,b]
Frasera carolinensis	18559	Roots & lvs.	188	1	2.45	o at 11,500 p.o.[a]	o at 400 s.c.[a]
Frasera parryi	15236	Roots	300	2	0.91	o at 2000 p.o.[a] o at 1000 p.o.[b]	o at 140 s.c.[a]
Gentiana acuta	17173	Entire	209	1	0.75	o at 10,720	o at 200 p.o.[a]
Gentiana calycosa	16573	Entire	66	1		o at 11,840 p.o.	
Gentiana aff. campanuliformis	16971	Entire	23	1		o at 488 p.o.[a]	
Gentiana aff. detonsa	17039	Entire	173	1	0.59	o at 5220 p.o.[a,b]	o at 200 p.o.[a]
Gentiana lutea	16521	Root	210	1	1.24	o at 13,400 p.o.[a]	o at 652 p.o.[a]
Gentiana parphyria	17492	Entire	146	1	1.56	o at 5550 p.o.[a]	o at 394 p.o.[a]
Gentiana saponaria	17496	Entire	230	1	1.00	o at 5510 p.o.[a]	o at 640 p.o.[a]
Gentiana sceptrum	17006	Entire	122	1	2.05	o at 3730 p.o.[a]	o at 136 s.c.[a,b]
Gentiana thermalis	18502	Entire	198	1	4.39	o at 6450 p.o.[a]	o at 230 s.c.[a]
Gentiana sp. "Corpus huait"	16047	Entire	80	2+3	0.70	o at 1300 p.o.[a,b]	+++ at 50 s.c.[a]
Gentiana sp.	16643	Roots	224	1	1.57	o at 13,860 p.o.[a,b]	o at 452 p.o.[a,b]
Gentiana sp.	18628	Upper	76	1	1.02	o at 2200 p.o.[a]	o at 200 s.c.[a]
Halenia deflexa	17027	Entire	209	1	0.86	o at 5820 p.o.[a]	o at 234 p.o.[a,b]
Limnanthemum aquaticum	16688	Entire	175	1	2.04	o at 1540 p.o.[a]	o at 310 p.o.[a]
Limnanthemum humboldtianum	16973	Entire	124	1	1.17	o at 2043 p.o.[a] o at 1021 p.o.[b]	o at 224 p.o.[a,b]
Limnanthus sp.	18274	Upper	200	1	4.79	o at 4920 p.o.[a]	o at 400 s.c.[a]
Menyanthes trifoliata	16524	Leaves	185	1	1.30	o at 6238 p.o.[a]	o at 240 p.o.[a]
Sabbatia campanulata	16617	Entire	32	1		o at 1648 p.o.[a]	
Sabbatia paniculata	16733	Entire	125	1	0.68	o at 3332 p.o.[a]	o at 180 p.o.[a]
Sabbatia difformis	16690	Entire	134	1	1.15	o at 4068 p.o.[a]	o at 324 p.o.[a]
Sabbatia elliottii	17160	Entire	185	1	1.62	o at 4640 p.o.[a] o at 9280 p.o.[b]	o at 222 p.o.[a,b]
Schultesia australis	17010	Entire	133	1	0.72	o at 3620 p.o.[a,b]	o at 145 p.o.[a,b]
Schultesia guianensis	17251	Entire	178	1	0.94	o at 5460 p.o.[a]	o at 420 p.o.[a]
Schultesia lisianthoides	16164	Entire	500	2	1.27	o at 8800 p.o.[a] +++ at 6600 p.o.[b]	+ at 1100 p.o.[a]
Schultesia lisianthoides	16164	Entire	250	1	4.65	o at 7340 p.o.[b] + at 7340 p.o.[a]	o at 1160 s.c.[b] o at 580 s.c.[a]
Schultesia lisianthoides	15107	Entire	484	1	3.27	o at 5340 p.o.[c,d]	o at 668 s.c.[c] o at 434 s.c.[d]
Swertia chirata	16528	Entire	215	1	2.09	o at 2148 p.o.[a]	o at 238 p.o.[a]
Swertia radiata	17051	Entire	200	1	0.69	o at 8260 p.o.[a,b]	o at 250 p.o.[a,b]
Tachia guianensis	18055	Branches & lvs.	210	1	4.11	o at 500 p.o.[a]	o at 752 s.c.[a]
			GERANIACEAE				
Erodium cicutarium	16757	Upper	200	1	2.40	o at 3385 p.o.[a] o at 6760 p.o.[b]	o at 284 p.o.[a,b]
Geranium robertianum	16904	Entire	89	1		+ at 990 p.o.[a]	

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. +Chloroform res.
			GESNERIACEAE				
Bellonia spinosa	16217	Branches & lvs.	26	1		0 at 808 p.o.[a]	
Tussacia pulchella	18914	Entire	150	1	1.19	0 at 3580 p.o.[a]	0 at 50 s.c.[a]
			GUTTIFERAE				
Mammea americana	15872	Leaves	407	1	1.14	0 at 6660 p.o.[c,d]	0 at 360 s.c.[c,d]
Psorospermum febrifugum	19117	Bark	200	1	0.60	0 at 6740 p.o.[a]	0 at 300 s.c.[a]
			HALORAGIDACEAE				
Gunnera sp.	16289	Leaves	160	1	3.08	0 at 2860 p.o.[a] 0 at 1430 p.o.[b]	0 at 760 p.o.[a] 0 at 76 s.c.[b]
			HIPPOCRATACEAE				
Cheiloclinium cognatum	18156	Bark	525	1	0.16	0 at 8760 p.o.[a]	0 at 280 s.c.[a]
Hippocratea volubilis	17486	Entire	263	1	0.05	0 at 2550 p.o.[a]	
			HUMIRIACEAE				
Saccaglottis gabonensis	18464	Bark	218	1	0.20	0 at 3400 p.o.[a]	0 at 112 s.c.[a,b]
			HYDROCHARITACEAE				
Elodea densa	18165	Stems & lvs.	201	1	2.32	0 at 3860 p.o.[a,b]	0 at 400 s.c.[a] 0 at 800 s.c.[b]
			IRIDACEAE				
Iris sp.	18578	Rhizomes	168	1	0.45	0 at 2380 p.o.[a] 0 at 4760 p.o.[b]	0 at 188 s.c.[a,b]
Sisyrinchium bellum	16342	Entire	200	1	0.17	0 at 7360 p.o.[a]	0 at 24 s.c.[a,b]
			JUGLANDACEAE				
Hicoria pecan	16481	Bark	200	1	0.15	0 at 2208 p.o.[a]	0 at 59 p.o.[a]
			KOEBERLINIACEAE				
Canotia holacantha	16031	Branches	200	1	0.40	0 at 5740 p.o.[a] 0 at 5620 p.o.[b]	0 at 216 p.o.[a] ++ at 108 p.o.[b]
			LABIATAE				
Ajuga iva	18509	Entire	164	1	1.94	0 at 2090 p.o.[a]	+ at 108 s.c.[a]
Ajuga reptens	16867	Tops with flowers	36	1		0 at 4960 p.o.[a]	
Clinopodium nepeta	15954	Entire	145	1	0.36	0 at 1040 p.o.[a,b]	0 at 56 p.o.[a,b]
Cunila origanoides	15495	?	141	1	0.60	0 at 4480 p.o.[a]	0 at 28 s.c.[a] 0 at 14 s.c.[b]
Glechoma hederacea	16409	Entire	145	1	4.70	0 at 3760 p.o.[a]	0 at 76 p.o.[a]
Glechoma hederacea	16523	Upper	250	1	6.10	0 at 3795 p.o.[a] 0 at 7590 p.o.[b]	0 at 416 p.o.[a,b]
Hyptis pectinata	17483	Tops with flowers	184	1	0.54	0 at 3360 p.o.[a]	0 at 249 p.o.[a]
Hyptis rhytidea	18795	Stems & roots	200	1	0.93	0 at 5490 p.o.[a]	0 at 372 s.c.[a]
Hyptis rhytidea	18708	Tops & lvs.	200	1	0.63	0 at 7520 p.o.[a]	0 at 390 s.c.[a]
Leonurus cardiaca	16610	Entire	170	1	0.40	0 at 4160 p.o.[a,b]	0 at 105 p.o.[a,b]
Leonurus cardiaca	16794	Lower stems & roots	200	1	0.33	0 at 2418 p.o.[a,b]	0 at 100 p.o.[a,b]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			LABIATAE—*continued*				
Leonurus sibiricus	17783	Entire	235	1	1.83	o at 3520 p.o.[a]	o at 308 p.o.[a]
Leonurus sibiricus	17783	Entire	443	1	1.60	o at 3900 p.o.[c]	o at 250 s.c.[c]
						o at 5200 p.o.[d]	o at 375 s.c.[d]
Lycopus americanus	16853	Entire	120	1	9.38	o at 2068 p.o.[a]	o at 194 p.o.[a]
						o at 3102 p.o.[b]	o at 388 p.o.[b]
Marrubium vulgare	16145	?	117	1	3.24	o at 2960 p.o.[a,b]	o at 184 p.o.[a]
							+ at 184 p.o.[b]
Marrubium vulgare	17240	Entire	267	1	3.30	o at 6620 p.o.[a]	o at 520 s.c.[a]
O. imum basilicum	16891	Upper	192	1	3.50	+ at 4912 p.o.[a]	o at 408 p.o.[a,b]
						o at 4920 p.o.[b]	
Ocimum viride	17773	Entire	205	1	0.16	o at 2750 p.o.[a]	o at 90 s.c.[a]
Pycnanthemum pilosum	17468	Entire	260	1	0.47	o at 3130 p.o.[a]	o at 333 p.o.[a]
Scutellaria angustifolia	15656	Entire	187	1	0.08	o at 10,000 p.o.[a]	o at 19 s.c.[a]
Scutellaria californica	16572	Upper part	225	1	1.08	o at 11,676 p.o.[a,b]	o at 644 p.o.[a,b]
Zizyphora tenuior	17813	Entire	117	1	1.06	o at 1420 p.o.[a]	o at 117 s.c.[a]
			LAURACEAE				
Benzoin aestivale	16704	Roots	190	1	1.00	o at 2080 p.o.[a]	o at 137 p.o.[a]
Nectandra rodioei	16119	Bark	435	1		o at 1700 p.o.[c]	
						o at 850 p.o.[d]	
Nectandra rodioei	16119	Bark	200	1	0.51	o at 1280 p.o.[a]	o at 92 s.c.[a]
							o at 46 s.c.[b]
			LEGUMINOSAE				
Afrormosia laxiflora	18457	Roots	220	1	0.37	+ at 200 p.o.[a,b]	o at 78 s.c.[a,b]
Anneslia eriophylla	16763	Stems	200	1	0.49	o at 1165 p.o.[a]	o at 308 p.o.[a]
Anneslia eriophylla	17829	Entire	230	1	0.59	o at 2820 p.o.[a]	o at 260 s.c.[a]
Baptisia tinctoria	16513	Roots	200	1	0.64	o at 1600 p.o.[a]	o at 92 p.o.[a]
Bauhinia reticulata	17340	Roots	229	1	0.04	o at 1660 p.o.[a]	
Caesalpinia crista	17022	Seeds	241	1	0.30	o at 3120 p.o.[a]	o at 126 p.o.[a]
Cassia fistula	16265	Fruits	200	1	0.12	o at 3880 p.o.[a,b]	o at 28 p.o.[a]
							++ at 28 p.o.[b]
Cassia fistula	16265	Stems & bark	235	1	2.56	o at 5400 p.o.[a,b]	o at 288 p.o.[a,b]
Cassia fistula	41RD 4074	Fruit	312	1	1.18	o at 4290 p.o.[b]	o at 280 s.c.[a,b]
Cercis canadensis	16696	Bark	240	1	0.29	o at 2864 p.o.[a]	o at 68 p.o.[a]
Cercis occidentalis	15657	Bark	200	1	0.26	o at 4360 p.o.[a]	o at 48 s.c.[a]
						o at 8720 p.o.[b]	+ at 48 s.c.[b]
Cercis occidentalis	15657	Bark	200	1	0.57	o at 4474 p.o.[a]	o at 416 p.o.[a]
Dalbergia cf. laevigata	17246	Bark	207	1	4.57	o at 2240 p.o.[a]	o at 512 p.o.[a]
Diphysa robinioides	16161	Branchlets & lvs.	200	1	0.05	o at 1920 p.o.[a]	o at 24 p.o.[a]
						+ at 1920 p.o.[b]	+ at 24 p.o.[b]
Diphysa robinioides	16161	Bark	218	1	0.58	o at 1980 p.o.[a,b]	o at 370 s.c.[b]
							o at 92 s.c.[a]
Ditremexa leptocarpa	16379A	Branchlets & lvs.	215	1	0.53	o at 2960 p.o.[a]	o at 28 p.o.[a]
						++ at 2960 p.o.[b]	o at 32 p.o.[b]
Haematoxylum cf. campechianum	17112	Bark	200	1	0.08	o at 2420 p.o.[a,b]	
Jupunba trapezifolia	16779	Bark	230	1	0.39	o at 940 p.o.[a,b]	o at 108 p.o.[a]
							o at 216 p.o.[b]
Parkinsonia aculeata	16466	Branches, stems, seeds	212	1	0.94	o at 8360 p.o.[a]	o at 288 p.o.[a]
Parkinsonia microphylla	16474	Branches, lvs. & fruits	200	1	0.50	o at 9240 p.o.[a]	o at 184 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			LEGUMINOSAE—*continued*				
Phaseolus lathyroides	17170	Entire	230	1	0.40	0 at 5520 p.o.[a]	0 at 115 p.o.[a]
Pithecellobium unguis-cati	16995	Bark	209	1	0.38	0 at 4930 p.o.[a,b]	0 at 132 p.o.[a,b]
Poinciana pulcherrima	15553	Branches, lvs. & flwrs.	235	1	0.02	0 at 4720 p.o.[a]	0 at 5.2 s.c.[a]
Psoralea pentaphylla	19035	Roots	190	1	0.37	0 at 7800 p.o.[a]	0 at 75 s.c.[a]
Pueraria thunbergiana	15868	Stems & lvs.	25	1		0 at 2150 p.o.[a]	
Pueraria thunbergiana	16732	Branches lvs.	135	1	0.82	0 at 2776 p.o.[a]	0 at 216 p.o.[a]
Robinia pseudo-acacia	18307	Bark	208	1	2.23	0 at 1000 p.o.[a]	0 at 300 s.c.[a]
Sophora secundiflora	17043	Seeds	208	1	3.55	0 at 26 p.o.[a] 0 at 65 p.o.[b]	0 at 14.5 p.o.[a,d] 0 at 20 p.o.[b]
			LEMNACEAE				
Lemna minor	16977	Entire	151	1	3.04	0 at 3380 p.o.[a,b]	0 at 140 p.o.[a,b,d]
			LINACEAE				
Linum chamissonis	17648	Entire	223	1	0.92	0 at 3410 p.o.[a]	0 at 472 p.o.[a]
			LOGANIACEAE				
Anthocleista frezoulsii	16834	Bark	200	1	0.45	0 at 6419 p.o.[a] 0 at 3209 p.o.[b]	+ at 220 p.o.[a] 0 at 110 p.o.[b]
Anthocleista frezoulsii	16834	Bark	480	1	1.48	0 at 8560 p.o.[c,d]	0 at 680 s.c.[c,d]
Strychnos brasiliensis	17905	Bark	178	1	1.28	+ at 3020 p.o.[a]	0 at 270 s.c.[a]
Strychnos fendleri	16655	Bark	200	1	1.21	0 at 4928 p.o.[a,b]	0 at 302 p.o.[a] 0 at 604 p.o.[b]
Strychnos pseudo-quina	18712	Bark	179	1	2.83	0 at 2010 p.o.[a]	0 at 944 s.c.[a]
			LYTHRACEAE				
Cuphea sp.	16290	Tops	35	1		0 at 904 p.o.[a]	
Heimia salicifolia	16708	Branches & lvs.	125	1	0.10	0 at 3547 p.o.[a]	0 at 100 p.o.[a]
			MAGNOLIACEAE				
Drimys winteri	16520	Bark	200	1	0.65	0 at 5820 p.o.[a]	0 at 652 p.o.[a]
Liriodendron tulipifera	15484	Bark	200	1	9.14	0 at 3200 p.o.[a,b]	0 at 296 p.o.[a,b]
Liriodendron tulipifera	15484	Bark	484	1	0.90	0 at 5100 p.o.[c,d]	0 at 100 s.c.[c] ++ at 100 s.c.[d]
Magnolia grandiflora	16341	Bark	200	1	3.23	0 at 5800 p.o.[a]	0 at 108 p.o.[a,b]
Magnolia virginiana	15899A	Bark	200	1	1.52	0 at 2140 p.o.[a,b]	0 at 600 p.o.[a]
Talauma mexicana	17931	Bark	223	1	1.35	0 at 6840 p.o.[a]	0 at 230 s.c.[a]
			MALPIGHIACEAE				
Banisteria leona	18180	Branches	212	1	0.20	0 at 4780 p.o.[a]	0 at 400 s.c.[a]
Byrsonima crassifolia	16866	Bark	193	1	0.21	0 at 6432 p.o.[a] 0 at 6520 p.o.[b]	0 at 112 p.o.[a]
			MALVACEAE				
Thespesia populnea	17424	Roots	218	1	0.01	0 at 2060 p.o.[a]	
Thespesia populnea	17424	Roots	240	1	0.06	0 at 3600 p.o.[a]	
			MELASTOMACEAE				
Miconia wildenowii	18691	Bark	193	1	0.07	0 at 1880 p.o.[a]	
Schwackaea cupheoides	17520	Entire	162	1	0.56	0 at 1880 p.o.[a]	0 at 200 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
				MELIACEAE			
Azadirachta indica	17711	Bark	245	1	0.06	0 at 1100 p.o.[a]	
Cabralea multijuga	17915	Bark	170	1	0.50	0 at 2200 p.o.[a]	0 at 50 s.c.[a]
Cabralea sp.	16713	Bark	200	1	14.11	0 at 1108 p.o.[a,b]	0 at 1228 p.o.[a,b,d]
Cabralea sp.	17908	Bark	152	1	1.32	0 at 1770 p.o.[a]	0 at 223 s.c.[a]
Cedrela toona	18214	Bark	205	1		0 at 3360 p.o.[a]	
Guarea trichilioides	16933	Roots	280	1	0.06	0 at 690 p.o.[a]	
Melia azedarach	9782	Bark	200	1	0.24	0 at 1760 p.o.[a,b]	0 at 48 p.o.[a]
Melia azedarach	15791	Bark	230	1	0.12	0 at 2240 p.o.[a]	
Pseudocedrela kotschyi	18462	Bark	220	1	0.35	0 at 2400 p.o.[a] 0 at 1200 p.o.[b]	0 at 210 s.c.[a,b]
Trichilia sp.	16300	Roots	200	1	1.31	+ at 1980 p.o.[a] 0 at 1980 p.o.[b]	+ at 436 p.o.[a] 0 at 218 p.o.[b]
				MENISPERMACEAE			
Burasaia madagascariensis	18097	Wood	200	1	0.82	0 at 1900 p.o.[a]	0 at 332 s.c.[a]
Chondodendron platiphyllum	17734	Roots	220	1	3.60	0 at 2290 p.o.[a]	0 at 880 p.o.[a]
Cissampelos pareira	16211	Roots	80	1	4.65	0 at 1208 p.o.[a] ++ at 1200 p.o.[b]	0 at 572 p.o.[a] ++ at 572 p.o.[b]
Cissampelos pareira	17114	Roots	423	1	1.56	0 at 1520 p.o.[c,d]	++ at 282 s.c.[c]
Coscinium fenestratum	17646	Roots	201	1	1.63	0 at 1240 p.o.[a]	0 at 344 p.o.[a]
Jateorhira columba	16093	Roots	325	1	2.65	0 at 710 p.o.[a]	0 at 530 s.c.[a]
				MONIMIACEAE			
Siparuna guianensis	18980	Bark	200	1	0.57	0 at 3900 p.o.[a]	0 at 300 s.c.[a]
				MORACEAE			
Morus alba	16910	Brances & lvs.	170	1	0.20	0 at 5128 p.o.[a,b]	0 at 62 p.o.[a,b]
Trophis racemosa	16275	Bark	90	1		0 at 656 p.o.[a]	
				MORINGACEAE			
Moringa oleifera	17342	Bark	200	1	0.10	0 at 1820 p.o.[a]	
				MUSACEAE			
Musa sapientum	17274	Roots	248	1	0.53	0 at 3160 p.o.[a]	0 at 184 p.o.[a]
				MYRICACEAE			
Comptonia peregrina	15595	Branches & lvs.	165	1	5.67	0 at 4040 p.o.[a] 0 at 8080 p.o.[b]	0 at 160 s.c.[a] 0 at 80 s.c.[b]
				MYRSINACEAE			
Parathesis serrulata	17280	Roots & stems	232	1	0.07	0 at 2910 p.o.[a]	
				MYRTACEAE			
Eucalyptus globulus	15543	Branchlets & lvs.	160	1	4.26	0 at 3480 p.o.[a,b]	0 at 264 p.o.[a,b]
Eucalyptus sp.	17716	Leaves	237	1	0.62	0 at 6870 p.o.[a]	0 at 230 s.c.[a]
Eugenia uniflora	18487	Roots	195	1	0.89	0 at 4480 p.o.[a]	0 at 384 s.c.[a]
Eugenia uniflora	18487	Branches	214	1	0.13	0 at 1900 p.o.[a]	0 at 528 s.c.[a]
				NYCTAGINACEAE			
Boerhaavia caribaea	18983	Entire	160	1	0.26	0 at 5540 p.o.[a]	0 at 67 s.c.[a]
Boerhaavia coccinea	16400	Entire	77	1		0 at 1490 p.o.[a] 0 at 2980 p.o.[b]	

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
				OCHNACEAE			
Sauvagesia erecta	18813	Entire	216	1	0.18	0 at 4470 p.o.[a]	0 at 115 s.c.[a]
				OLACACEAE			
Olax subscorpioidea	18461	Roots	222	1	0.64	0 at 2310 p.o.[a]	0 at 340 s.c.[a]
Ximenia americana	18808	Roots	200	1		0 at 3400 p.o.[a]	
				OLEACEAE			
Chionanthus virginica	16740	Roots	240	1	2.42	0 at 12,134 p.o.[a,b]	0 at 388 p.o.[a,b]
Fraxinus chinensis	16132	Bark	400	2	1.60	0 at 9750 p.o.[b]	0 at 980 p.o.[b]
						0 at 10,000 p.o.[a]	0 at 1000 p.o.[a]
Fraxinus chinensis	16132	Wood	790	2	3.60	0 at 2540 p.o.[a,b]	0 at 500 p.o.[a]
							0 at 1060 p.o.[b]
Fraxinus chinensis	17287	Bark	290	1	1.94	0 at 5100 p.o.[a]	0 at 420 p.o.[a]
						0 at 1275 s.c.[a]	0 at 210 s.c.[a]
Fraxinus chinensis	17625	Bark	211	1	1.36	0 at 3100 p.o.[a]	0 at 200 p.o.[a]
Fraxinus chinensis	17287	Bark	415	1	1.35	0 at 9060 p.o.[c]	0 at 800 s.c.[c]
						0 at 13,590 p.o.[d]	0 at 400 s.c.[d]
Osmanthus americana	17420	Roots	258	1	5.60	0 at 11,520 p.o.[a]	0 at 1600 p.o.[a]
Syringa oblata	17097	Branches & lvs.	214	1	1.06	0 at 1575 p.o.[a]	0 at 432 p.o.[a]
				ONAGRACEAE			
Fuchsia regia	18949	Roots	194	1	0.76	0 at 6940 p.o.[a]	0 at 444 s.c.[a]
Oenothera biennis	17035	Entire	188	1	0.04	0 at 968 p.o.[a,b]	
				OXALIDACEAE			
Averrhoa carambola	17151	Roots	198	1	0.03	0 at 2056 p.o.[a]	
Oxalis articulata	17640	Entire	232	1	0.49	0 at 3120 p.o.[a]	0 at 300 p.o.[a]
				PALMAE			
Cocos nucifera	17422	Roots	216	1	0.06	0 at 1080 p.o.[a]	
				PAPAVERACEAE			
Argemone mexicana	18788	Entire	217	1	0.90	0 at 7160 p.o.[a]	0 at 218 s.c.[a]
				PASSIFLORACEAE			
Passiflora bryonioides	16918	Entire	105	1	0.89	0 at 2910 p.o.[a,b]	0 at 90 p.o.[a]
							0 at 270 p.o.[b]
Passiflora incarnata	18935	Roots	227	1	1.35	0 at 5580 p.o.[a]	0 at 186 s.c.[a]
Passiflora ligularis	16195	Leaves	145	1	0.99	0 at 2160 p.o.[a,b]	0 at 100 p.o.[a,b]
Passiflora maliformis	16197	Leaves & fruits	200	1	5.74	0 at 2940 p.o.[a,b]	0 at 136 p.o.[a,b]
Passiflora mexicana	17261	Stems & lvs.	226	1	0.63	0 at 10,320[a]	0 at 364 p.o.[a]
				PICRODENDRACEAE			
Picrodendron baccatum	16236	?	79	1	4.30	0 at 1320 p.o.[a]	0 at 10 s.c.[a]
						0 at 165 s.c.[a]	
Picrodendron baccatum	16472	Stems	180	1	1.07	++ at 3474 p.o.[a]	0 at 600 p.o.[a]
Picrodendron macrocarpum	16044	Branchlets	144	2	0.75	0 at 158 s.c.[b]	0 at 170 s.c.[a]
						0 at 394 s.c.[a]	+ at 170 s.c.[b]
Picrodendron macrocarpum	16333	Bark	200	1	2.19	0 at 1920 p.o.[a]	0 at 192 p.o.[a]
Picrodendron macrocarpum	16044	Leaves	219	1	1.80	0 at 500 s.c.[a]	+ at 290 s.c.[a]
						+ at 1000 p.o.[b]	0 at 145 s.c.[b]
Picrodendron macrocarpum	16227	Roots	427	1	0.21	0 at 5560 p.o.[c]	0 at 50 s.c.[c]
						0 at 2780 p.o.[d]	0 at 100 s.c.[d]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			PITTOSPORACEAE				
Pittosporum nigricans	15628	Branchlets & livs.	300	1	0.48	0 at 2620 p.o.[a,b]	0 at 316 p.o.[a,b]
			POLEMONIACEAE				
Loeselia mexicana	16844	Entire	200	1	0.28	0 at 1858 p.o.[a]	0 at 110 p.o.[a,b]
			POLYGONACEAE				
Polygonum aviculare	9673	Entire	166	1	2.72	0 at 3960 p.o.[a,b]	0 at 96 p.o.[a] 0 at 120 p.o.[b]
Polygonum aviculare	16974	Entire	201	1	0.28	0 at 1370 p.o.[a,b]	0 at 80 p.o.[a] 0 at 160 p.o.[b]
Polygonum aviculare	18213	Entire	460	1	4.87	0 at 1140 p.o.[c,d]	0 at 296 s.c.[c,d]
Rumex cf. crispus	17735	Roots	198	1	0.09	0 at 4220 p.o.[a]	
			RANUNCULACEAE				
Clematis caracasana	9837	?	108	1	0.48	0 at 3120 p.o.[a] 0 at 3760 p.o.[b]	0 at 24 p.o.[a,b]
			RHAMNACEAE				
Ceanothus americanus	15547	Roots	200	1	0.11	0 at 3240 p.o.[a]	0 at 20 s.c.[a] 0 at 24 p.o.[b]
Ceanothus integerrimus	17019	Roots	183	1	0.25	0 at 2380 p.o.[a,d]	0 at 91 p.o.[a,d]
Ceanothus integerrimus	18361	Bark	269	1	1.21	0 at 12,200 p.o.[c,d]	0 at 244 s.c.[c,d]
Colubrina ferruginosa	16991	Bark	280	1		0 at 500 p.o.[a] 0 at 562 p.o.[b]	
			RHIZOPHORACEAE				
Rhizophora mangle	16002	Aërial roots	200	1		0 at 3440 p.o.[a,b]	0 at 24 p.o.[a,b]
Rhizophora mangle	16002	Branches	200	1	0.08	0 at 1240 p.o.[a,b]	0 at 20 p.o.[a,b]
			ROSACEAE				
Adenostoma sparsifolium	17230	Branches & lvs.	265	1	0.87	0 at 6255 p.o.[a]	0 at 400 p.o.[a]
Cowania stansburiana	16968	Bark	396	1	2.20	0 at 2400 p.o.[c,d]	0 at 100 s.c.[c,d]
Geum rivale	16522	Roots	200	1	0.23	0 at 2084 p.o.[a]	0 at 68 p.o.[a]
Kageneckia oblonga	16142	Branches, lvs., bark	200	1	0.60	0 at 3040 p.o.[a,b]	0 at 25 p.o.[a] 0 at 20 p.o.[b]
Margyricarpus setosus	16381A	Entire	194	1	0.07	0 at 4560 p.o.[a]	0 at 16 s.c.[a]
Potentilla recta	17067	Roots	314	1	0.08	0 at 8680 p.o.[a,b]	0 at 40 p.o.[a,b]
Sorbus scopulina	15558	Bark	200	1	4.80	0 at 3180 p.o.[a] + at 3180 p.o.[b]	0 at 270 p.o.[a,b]
Sorbus scopulina	17255	Bark	200	1	0.38	0 at 7000 p.o.[b] 0 at 1750 p.o.[a]	0 at 142 s.c.[a,b]
Sorbus scopulina	18403	Bark	527	1	4.78	0 at 4980 p.o.[c] 0 at 3320 p.o.[d]	0 at 204 s.c.[c] 0 at 508 s.c.[d]
Sorbus scopulina	15558	Bark	332	1	0.54	0 at 982 p.o.[b]	0 at 200 p.o.[b]
Spiraea tomentosa	19106	Entire	200	1		0 at 5520 p.o.[a]	
			RUBIACEAE				
Anisomeris obtusa	16898	Roots	180	1	0.12	0 at 1453 p.o.[a] 0 at 2906 p.o.[b]	0 at 36 p.o.[a]
Basanacantha annae	16320	Bark	200	1	0.06	0 at 3876 p.o.[a]	0 at 20 s.c.[a]
Bathysa cf. cuspidata	16321	Bark	200	1	0.11	0 at 5280 p.o.[a]	0 at 40 s.c.[a]
Borreria suaveolens	17620	Entire	190	1	0.24	0 at 4500 p.o.[a]	0 at 100 p.o.[a]
Bouvardia glaberrima	16920	Entire	200	1	0.16	0 at 5146 p.o.[a]	0 at 62 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			RUBIACEAE—*continued*				
Bouvardia ternifolia	17050	Entire	203	1	0.17	0 at 1980 p.o.[a] 0 at 3960 p.o.[b]	0 at 100 p.o.[a]
Calycophyllum candidissimum	15139	Bark	1800	2,3		0 at 8000 p.o.[a]	0 at 1000 p.o.[a]
Catesbaea spinosa	18590	Roots	210	1	0.30	0 at 1420 p.o.[a]	0 at 130 s.c.[a]
Corynanthe pachyceras	18670	Bark	200	1	0.64	0 at 2010 p.o.[a]	0 at 68 s.c.[a]
Coutarea hexandra	17674	Bark	294	1	1.37	0 at 5970 p.o.[a]	0 at 804 p.o.[a]
Coutarea hexandra	17674	Bark	418	1	0.70	0 at 5120 p.o.[c,d]	0 at 100 s.c.[c] 0 at 50 s.c.[d]
Couteria pterosperma	16102	Bark	200	1	2.05	0 at 2430 p.o.[a] 0 at 1214 p.o.[b]	0 at 100 p.o.[a] 0 at 125 p.o.[b]
Couteria sp.	16128	Bark	200	1	1.71	0 at 5800 p.o.[a,b]	0 at 500 p.o.[a]
Crossopteryx febrifuga	18463	Bark	210	1	0.25	0 at 2925 p.o.[a] 0 at 3900 p.o.[b]	0 at 120 s.c.[a,b]
Crossopteryx kotschyana	17774	Roots	210	1	0.24	0 at 1105 p.o.[a]	0 at 50 s.c.[a]
Crossopteryx kotschyana	17774	Bark	116	1	0.84	0 at 4770 p.o.[a]	0 at 196 s.c.[a]
Exostema caribaeum	15174	Bark	200	1	0.12	0 at 2380 p.o.[a,b]	0 at 82 p.o.[a]
Exostema caribaeum	15916	Bark	437	1	0.05	0 at 2660 p.o.[c,d]	0 at 30 s.c.[c,d]
Gaertneria capitata	18533	Bark	207	1	0.64	0 at 4350 p.o.[a]	0 at 178 s.c.[a]
Galium aparine	16431	Stems	200	1	0.92	0 at 11,320 p.o.[a]	0 at 408 p.o.[a]
Guettarda verticillata	18538	Bark	204	1	2.09	0 at 5480 p.o.[a]	0 at 113 s.c.[a]
Ixora coccinea	17659	Bark	209	1	0.08	0 at 4180 p.o.[a]	
Hymenodiction excelsum	17769	Bark	207	1	0.55	0 at 1185 s.c.[a]	0 at 214 p.o.[a]
Laugeria resinosa	16310	Bark	200	1	0.37	0 at 3240 p.o.[a]	0 at 20 s.c.[a] 0 at 10 s.c.[b]
Mitragyna stipulosa	18458	Bark	242	1	0.13	0 at 2170 p.o.[a,b]	0 at 100 s.c.[a]
Mussaenda landia	18535	Bark	203	1	1.72	0 at 5240 p.o.[a]	0 at 800 s.c.[a]
Oldenlandia corymbosa	16398	Entire	95	1		0 at 3140 p.o.[a,b]	
Pentas lanceolata	17817	Roots	150	1	0.16	0 at 4230 p.o.[a]	0 at 39 s.c.[a]
Portlandia grandiflora	17371	Bark	200	1	0.41	0 at 2560 p.o.[a]	0 at 210 p.o.[a]
Remijia peruviana	17088	Bark	200	1	0.50	++++ at 530 p.o.[a] 0 at 2120 p.o.[b]	0 at 96 p.o.[a] 0 at 192 p.o.[b]
Richardia brasiliensis	16815	Entire	210	1	1.72	0 at 6220 p.o.[a,b]	0 at 208 p.o.[a,b]
Sarcocephalus cordatus	15005	Bark	200	1	0.25	0 at 820 p.o.[a]	0 at 32 s.c.[a] 0 at 16 s.c.[b]
Sarcocephalus esculentus	17772	Roots	211	1		0 at 6140 p.o.[a]	
Sickingia calderoniana	17268	Roots	220	1	0.30	0 at 2610 p.o.[a]	0 at 83 p.o.[a]
Sickingia sp.	16743	Bark	240	1	0.14	0 at 837 p.o.[a,b]	0 at 64 p.o.[a]
Strumpfia maritima	18841	Roots	207	1	0.11	0 at 5480 p.o.[a]	
Uncaria guianensis	17896	Branches	237	1	0.14	0 at 3620 p.o.[a]	0 at 85 s.c.[a]
			RUTACEAE				
Amyris elemifera	15951	Wood	45	1	10.30	0 at 40 s.c.[a]	0 at 1640 s.c.[a] 0 at 840 s.c.[b]
Cneoridium dumosum	16465	Branches & lvs.	215	1	2.12	0 at 5568 p.o.[a]	0 at 600 p.o.[a]
Cusparia angostura	16519	Bark	250	1	3.31	0 at 3894 p.o.[a,b]	0 at 276 p.o.[a]
Dictamnus albus	16460	Stems & lvs.	139	1	0.41	0 at 3600 p.o.[a]	0 at 110 p.o.[a]
Hortia arborea	18642	Bark	200	1	0.44	0 at 2055 p.o.[a]	0 at 186 s.c.[a]
Hortia sp.	16085	Bark	450	2	0.94	0 at 2240 p.o.[a,b]	0 at 2400 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
				RUTACEAE—*continued*			
Orixa japonica	18157	Roots	195	1	0.96	+ at 4720 p.o.[a]	o at 340 s.c.[a]
Ptelea trifoliata	16526	Bark	195	1	6.83	+ at 13,500 p.o.[a] o at 13,500 p.o.[b]	o at 1204 p.o.[a]
Ruta graveolens	16792	?	200	1	4.26	o at 3760 p.o.[a]	o at 387 p.o.[a] o at 258 p.o.[b]
Spathelia sorbifolia	16234	Branches & lvs.	215	1	8.88	o at 4040 p.o.[a] o at 2020 p.o.[b]	o at 728 p.o.[a,b]
Toddalia aculeata	18536	Roots	221	1	4.61	o at 1000 p.o.[a]	o at 220 s.c.[a]
Zanthoxylum flavum	16062	Branchlets	147	3		o at 1740 p.o.[a,b]	
Zanthoxylum sp.	16781	Bark	220	1	3.23	o at 1699 p.o.[a] o at 3398 p.o.[b]	o at 99 p.o.[a]
				SALICACEAE			
Populus nigra	16531	Buds	210	1		o at 708 p.o.[a] ++ at 708 p.o.[b]	o at 1312 p.o.[a,b]
Populus tremuloides	17061	Bark	200	1	1.91	o at 3000 p.o.[a,b]	o at 332 p.o.[a,b]
				SANTALACEAE			
Comandra richardsiana	18483	Entire	200	1	0.13	o at 1640 p.o.[a]	o at 552 s.c.[a]
				SAPINDACEAE			
Dondonaea viscosa var. angustifolia	15567	Stems	200	1	0.37	o at 920 p.o.[a,b]	o at 100 s.c.[a]
Nephelium litchi	18534	Roots	226	1	0.14	o at 3040 p.o.[a]	o at 82 s.c.[a]
				SAPOTACEAE			
Bumelia angustifolia	16958	Bark of roots	189	1	0.13	o at 778 p.o.[a,b,d]	o at 47 p.o.[a,b]
Lucuma salicifolia	15976	Branches & lvs.	128	1	1.60	o at 4160 p.o.[a]	o at 72 p.o.[a]
Mimusops elengi	16214	Bark	200	1	0.14	o at 4140 p.o.[a]	o at 32 p.o.[a,b]
				SAURURACEAE			
Anemopsis californica	9797	?	144	1	0.43	o at 5560 p.o.[a,b]	o at 64 p.o.[a] + at 64 p.o.[b]
Anemopsis californica	9797	Entire	228	1	6.34	+ at 6720 p.o.[b]	o at 536 p.o.[b] o at 536 s.c.[b]
				SAXIFRAGACEAE			
Dichroa febrifuga	17288	Roots	226	1	0.25	++++ at 2030 p.o.[a] o at 2030 p.o.[b]	++++ at 104 p.o.[a] ++ at 52 s.c.[a] + at 104 p.o.[b]
Dichroa febrifuga	17288	Roots	140	1	1.04	++++ at 1115 p.o.[a]	+++ at 100 p.o.[a] ++ at 200 p.o.[b]
Dichroa febrifuga	18885	Stems	202	1	2.31	+++ at 3240 p.o.[a] o at 2160 p.o.[b]	+ at 924 po.[a]
Dichroa febrifuga	18885	Roots	201	1	0.79	++++ at 2360 p.o.[a] +++ at 2360 p.o.[b]	++++ at 196 p.o.[a]
Dichroa febrifuga	18660	Leaves	200	1	2.40	+++ at 1520 p.o.[a]	+++ at 440 p.o.[a] o at 440 s.c.[b]
Hydrangea arborescens	18273	Roots	407	1	2.64	o at 5800 p.o.[a] o at 2900 p.o.[c] o at 8700 p.o.[b]	o at 720 s.c.[a,b] + at 720 s.c.[c]
				SCROPHULARIACEAE			
Aureolaria flava	16435	Stems & lvs.	200	1	0.76	o at 3000 p.o.[a]	o at 204 p.o.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			SCROPHULARIACEAE—*continued*				
Capraria biflora	17755	Entire	230	1	0.99	o at 5860 p.o.[a]	o at 304 p.o.[a]
Fagelia hyssopifolia	17401	Entire	407	1	0.82	o at 8140 p.o.[c] o at 12,110 p.o.[d]	o at 352 s.c.[c,d]
Gratiola aurea	15698	Entire	458	1	2.00	o at 10,260 p.o.[c] o at 15,390 p.o.[d]	o at 180 s.c.[c,d]
			SIMAROUBACEAE				
Ailanthus excelsa	17688	Bark	157	1	0.27	o at 562 s.c.[a]	o at 54 s.c.[a]
Ailanthus glandulosa	16035	Wood	124	2	0.75	o at 540 p.o.[a]	o at 50 s.c.[a]
Ailanthus glandulosa	16035	Wood	124	3	1.50		++ at 12.5 s.c.[a]
Ailanthus imberbiflora	16433	Bark	250	1	0.03	++ at 302 p.o.[a]	+++ at 0.5 s.c.[a]
Alvaradoa arborescens	15978	Wood	137	2	0.23	o at 230 s.c.[a,b]	o at 100 s.c.[a]
Alvaradoa jamaicensis	16318	Roots	176	1	0.11	o at 1920 p.o.[a,b]	o at 28 p.o.[a,b]
Alvaradoa jamaicensis	16318	Stems	191	1	0.14	o at 1122 p.o.[a]	o at 104 p.o.[a]
Balanites aegyptica	17140	Roots	200	1	0.37	o at 5860 p.o.[a,b]	+ at 79 p.o.[a] o at 158 p.o.[b]
Balanites aegyptica	17185	Roots	258	1	0.54	o at 7640 p.o.[a]	o at 198 p.o.[a]
Balanites aegyptica	17185	Seeds	225	1	1.47	o at 215 s.c.[a]	o at 640 s.c.[a]
Balanites maughamii	16936	Roots	200	1	0.19	o at 3906 p.o.[a,b]	o at 108 p.o.[a]
Balanites roxburghii	15119	Bark	200	1	1.69	o at 880 p.o.[a,b]	o at 196 p.o.[a] o at 96 p.o.[b]
Balanites tomentosa	17139	Roots	200	1	0.44	o at 3560 p.o.[a]	o at 117 p.o.[a] +++ at 117 p.o.[b]
Balanites wilsoniana	16737	Roots	240	1	0.23	o at 1032 p.o.[a]	o at 50 p.o.[a]
Brucea antidysenterica	17141	Roots	174	1	0.07	o at 4480 p.o.[a]	
Cadellia monostylis	16682	Bark	200	1	0.10	o at 3484 p.o.[a]	o at 49 p.o.[a]
Cadellia monostylis	16937	Roots	238	1	0.07	o at 2350 p.o.[a]	
Cadellia pentastylis	16388	Wood	188	1	0.14	o at 3920 p.o.[a]	o at 16 s.c.[a] o at 8 s.c.[b]
Cadellia pentastylis	16388	Bark	200	1	0.56	o at 1380 p.o.[a]	o at 88 p.o.[a]
Cadellia pentastylis	16935	Roots	210	1	0.04	o at 4838 p.o.[a,b]	o at 36 p.o.[a]
Castela coccinea	16378A	?	200	1	0.41	o at 5240 p.o.[a]	o at 52 s.c.[a]
Castela depressa	16134	Branchlets	340	2	0.30	++ at 92 s.c.[a]	++ at 30 s.c.[a] o at 30 s.c.[b]
Castela depressa	16361	Roots	1000	1			++ at 50 p.o.[a] o at 50 p.o.[b]
Castela depressa	16361	Stems	2300	1		+++ at 500 p.o.[a]	++ at 100 p.o.[a]
Castela macrophylla	16317	Roots	248	1	1.79	+++ at 910 p.o.[a]	o at 96 p.o.[a]
Castela macrophylla	16317	Stems	200	1	0.54	+++ at 740 p.o.[a]	++ at 63 p.o.[a]
Castela spinosa	16467	Roots	200	1	0.41	o at 620 p.o.[a]	o at 136 p.o.[a]
Castela spinosa	17571	Roots	203	1		++++ at 1180 p.o.[a]	
Castela tortuosa	15885	Fruits	235	2	0.65	o at 440 p.o.[a]	++++ at 490 p.o.[a]
Castela tortuosa	15885	Roots	600	2	3.26		++++ at 60 p.o.[a] o at 30 p.o.[a]
Castela tortuosa	15885	Leaves	224	2	0.76	++++ at 370 p.o.[a]	++ at 12.5 p.o.[a]
Castela tweedii	17903	Stems	205	1	1.25	++++ at 300 s.c.[a]	++++ at 50 s.c.[a]
Castela tweedii	16371	Roots	194	1	0.60	++++ at 500 p.o.[a]	o at 12 p.o.[a]
Hannoa klaineana	17293	Roots	204	1		o at 2790 p.o.[a]	
Hannoa undulata	17714	Roots	211	1		o at 365 s.c.[a]	
Harrisonia abyssinica	16903	Roots	208	1	3.95	o at 1484 p.o.[a,b,d]	o at 864 p.o.[a,b]
Harrisonia sp.	17048	Roots	224	1	0.45	o at 3090 p.o.[a,b]	o at 234 p.o.[a] o at 312 p.o.[b]
Irvingia gabonensis	16912	Roots	121	1	0.05	o at 1860 p.o.[a]	
Irvingia gabonensis	15940	Wood	40	2+3		o at 1400 p.o.[a]	
Irvingia smithii	16846 16913	Roots	258	1		o at 2230 p.o.[a]	

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			SIMAROUBACEAE—*continued*				
Kirkia acuminata	16934	Roots	188	1	0.25	o at 1362 p.o.[a,b]	o at 176 p.o.[a]
Klainedoxa gabonensis	16838	Roots	210	1	0.16	o at 1750 p.o.[a]	o at 52 p.o.[a]
Klainedoxa grandifolia	17766	Stems	229	1	0.45	o at 100 s.c.[a]	o at 132 s.c.[a]
Mannia africana	16738	Roots	183	1	2.18	o at 1180 p.o.[a,b]	++++ at 188 p.o.[a] +++ at 94 p.o.[a] o at 94 p.o.[b]
Mannia africana	17765	Stems	177	1	0.18	o at 660 p.o.[a]	++ at 19 s.c.[b]
Odyendea zimmermannii	17143	Roots	110	1		+++ at 476 p.o.[a]	
Picramnia antidesma	16796	Branches	240	1	0.35	o at 3864 p.o.[a,b]	o at 128 p.o.[a] ++ at 128 p.o.[b]
Picramnia carpinterae	15979	Wood	62	2	1.52	o at 160 s.c.[a,b]	o at 100 s.c.[a,b]
Picramnia locuples	15980	Wood	60	2	1.04		o at 72 s.c.[a] o at 90 s.c.[b]
Picramnia longissima	16384	Roots	200	1	0.18	o at 3800 p.o.[a]	o at 24 s.c.[a]
Picramnia pentandra	16054	Stems	2300	2, 4	0.26	+ at 2200 p.o.[a] o at 2200 p.o.[b]	o at 200 s.c.[a]
Picramnia pentandra	16380	Roots	200	1	0.21	o at 1720 p.o.[a]	o at 1300 p.o.[a]
Picramnia selowii	17381	Roots	241	1	0.10	o at 3480 p.o.[a]	o at 40 p.o.[a]
Picramnia xalapensis	17009	Roots	238	1	0.21	o at 2934 p.o.[a,b]	o at 130 p.o.[a,b]
Picramnia sp.	17023	Bark	243	1	0.27	o at 522 p.o.[a] ++ at 522 p.o.[b]	o at 64 p.o.[a,b]
Picramnia sp.	17554	Bark	238	1	3.00	o at 2150 p.o.[a] o at 344 s.c.[a]	o at 446 p.o.[a] o at 223 s.c.[a]
Picramnia sp.	16392	Branches	220	1	0.19	o at 5060 p.o.[a]	o at 20 s.c.[a]
Picramnia sp.	16930	Roots	200	1	0.28	o at 3340 p.o.[a,b]	o at 168 p.o.[a]
Picrasma antillana	16784	Wood	200	1	0.30	o at 1284 p.o.[a]	o at 76 p.o.[a,b]
Picrasma crenata	17023	Roots	176	1	0.55	o at 4110 p.o.[a,b]	o at 120 p.o.[a] o at 240 p.o.[b]
Picrasma excelsa	16529	Wood	197	1	0.48	o at 378 p.o.[a]	o at 130 s.c.[a]
Picrasma nepalensis	17472	Roots	226	1	0.14	o at 215 s.c.[a]	++ at 25 s.c.[a]
Picrasma sp.	17713	Wood	197	1	0.30	o at 1400 s.c.[a]	o at 112 s.c.[a]
Picrasma sp.	17713	Bark	208	1	0.32	o at 1095 s.c.[a]	o at 150 s.c.[a]
Picrolemma sprucei	18872	Roots	418	1	2.91	++++ at 50 s.c.[a] o at 1100 p.o.[b] o at 1000 p.o.[a]	++++ at 10 s.c.[a]
Quassia amara	15984	Wood	100	2			
Samadera indica	16965	Roots	140	1	0.07	o at 534 p.o.[a]	o at 20 p.o.[a]
Samadera indica	18406	Seeds	326	1	3.92	o at 225 p.o.[a] o at 50 s.c.[a] + at 75 s.c.[b]	o at 55 s.c.[a]
Simaba cedron	16168	Wood	390	1	0.31	o at 400 p.o.[a] o at 200 s.c.[a] o at 200 s.c.[b]	o at 40 p.o.[a] o at 20 s.c.[a]
Simaba cedron	18088	Wood	491	1	0.19	o at 85 s.c.[a]	o at 67 s.c.[a]
Simaba cedron	18067	Bark	555	1	0.41	o at 83 s.c.[a]	o at 92 s.c.[a]
Simaba cedron	18088	Roots	520	1	0.33	+ at 271 s.c.[a]	+ at 43.5 s.c.[a]
Simaba cedron	18767	Kernels	200	1	5.73	++++ at 50 s.c.[a]	++++ at 34 s.c.[a]
Simaba cuneata	16209	Wood	600	2	0.85	+ at 72 s.c.[a]	++ at 25 s.c.[a]
Simaba cuneata	16209	Bark	190	2	0.66	++ at 60 s.c.[a]	++++ at 10 s.c.[a] o at 10 s.c.[b]
Simaba cuneata	16210	Wood	60	1		o at 12 s.c.[a]	
Simaba guianensis	16222	Branchlets	100	2		o at 320 s.c.[a,b]	
Simaba insignis	17375	Bark	229	1	0.33	o at 5 s.c.[a]	++++ at 4 s.c.[a]
Simaba multiflora	16221	Wood	350	2	0.19	o at 320 s.c.[a] o at 256 s.c.[b]	++ at 120 s.c.[a]
Simaba trichilioides	16416	Roots	200	1	2.06	+++ at 834 p.o.[a] o at 834 p.o.[b]	o at 158 p.o.[a] ++ at 31 s.c.[a]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			SIMAROUBACEAE—*continued*				
Simaba sp. "Marupa blanca"	16312	Bark	251	1		o at 1280 p.o.[a] + at 320 s.c.[a] o at 320 s.c.[b]	o at 84 p.o.[a]
Simaba sp. "Marupa blanca"	16945	Bark	315	1	0.09	++ at 676 p.o.[a]	o at 31 p.o.[a] o at 15 s.c.[a]
Simaba sp.	18077	Wood	200	1	0.43	o at 2500 s.c.[a]	o at 200 s.c.[a]
Simaba sp.	18077	Roots	205	1	0.12	o at 720 s.c.[a]	o at 65 s.c.[a]
Simarouba amara	16137	Wood	800	2	0.45	++++ at 500 p.o.[a] +++ at 100 s.c.[a] o at 25 s.c.[b]	++++ at 25 p.o.[a] +++ at 1.5 s.c.[a] + at 3 s.c.[b]
Simarouba amara	16245	Branchlets	112	1	0.35	o at 1640 p.o.[a] o at 410 s.c.[b]	o at 60 p.o.[a] o at 48 s.c.[a]
Simarouba amara	16245	Bark	300	1	1.66	+++ at 3 s.c.[a]	
Simarouba amara	16245	Leaves	200	1	0.39	o at 60 s.c.[b]	o at 50 s.c.[a]
Simarouba amara	16468	Stems & bark	177	1	0.49	+ at 20 s.c.[a] o at 200 p.o.[a] o at 8 s.c.[b]	++++ at 32 p.o.[a] +++ at 5 sc.[a]
Simarouba amara	16527	Bark	200	1	2.08	+ at 28 s.c.[a] o at 28 s.c.[b]	o at 4.5 s.c.[a,b]
Simarouba amara var. opaca	15987	Wood	100	3	0.19	o at 50 s.c.[a,b]	
Simarouba amara var. opaca	15987	Wood	100	2		+ at 6 s.c.[a]	
Simarouba berteroana	15986	Wood	100	2	0.92		++++ at 0.5 s.c.[a]
Simarouba glauca var. latifolia	16375	Stems	187	1	0.09	++++ at 10 s.c.[a] o at 4 s.c.[b]	++++ at 1.0 s.c.[a] + at 1.0 s.c.[b]
Simarouba glauca var. latifolia	16375	Roots				++ at 55 p.o.[a] ++ at 5 s.c.[a]	++++ at 1 s.c.[a]
Simarouba tulae	17709	Stems	207	1	0.23	++++ at 40 s.c.[a]	++++ at 1.0 s.c.[a]
Simaroub tulae	17856	Roots	201	1	2.04	+++ at 5 s.c.[a]	++++ at 1.0 s.c.[a] + at 1.0 s.c.[b]
Simarouba versicolor var. pallida	17085	Bark	82	1		o at 64 s.c.[a]	
Suriana maritima	9168	Stems	205	1	0.05	+ at 4080 p.o.[a]	o at 62 p.o.[a]
Suriana maritima	16402	Stems	200	1	0.04	o at 4120 p.o.[a]	o at 96 s.c.[a] o at 48 s.c.[b]
"Marupa amarillo"	17086	Roots	177	1	0.62	o at 4460 p.o.[a]	o at 182 p.o.[a]
			SOLANACEAE				
Cestrum parqui	18252	Roots	215	1	1.22	o at 3320 p.o.[a]	o at 268 s.c.[a]
Cestrum sp.	17210	Stems	212	1	0.18	o at 3820 p.o.[a]	o at 73 p.o.[a]
Henoonia brittonii	16207	Roots	800	2	0.25	o at 2000 p.o.[a]	o at 200 p.o.[a]
Solanum angustifolium	17920	Stems	245	1	0.34	o at 2220 p.o.[a]	o at 100 s.c.[a]
Solanum crispum var. ligustrinum	17649	Stems	194	1	0.66	o at 2780 p.o.[a]	o at 400 p.o.[a]
Solanum glaucum	18145	Roots & stems	325	1	0.60	o at 4020 p.o.[a,b]	o at 480 s.c.[a] o at 120 s.c.[b]
Vestia lyciodes	16366	Branches & lvs.	143	1	7.25	o at 10,520 p.o.[a]	o at 208 p.o.[a]
			STERCULIACEAE				
Guazuma tomentosa	16138	Bark	200	1	0.17	o at 3440 p.o.[a,b]	o at 24 p.o.[a,b]
Guazuma ulmifolia	17108	Bark	200	1		o at 1650 p.o.[a]	
			SYMPLOCACEAE				
Symplocos tinctoria	17137	Roots	174	1	0.74	o at 1580 p.o.[a,b]	o at 190 p.o.[a,b]
Symplocos tinctoria	17137	Roots	394	1	0.37	o at 4850 p.o.[c,d]	o at 254 s.c.[c,d]

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			TERNSTROEMIACEAE				
Laplacea sp.?	18155	Bark	527	1	0.50	o at 2820 p.o.[a] ++ at 4230 p.o.[b]	o at 680 s.c[a,b]
			THYMELAEACEAE				
Daphne mezereum	9601	Roots	75	1	0.59	o at 2920 p.o.[a]	o at 32 p.o.[a,b]
			TILIACEAE				
Corchorus capsularis	17626	Entire	136	1	0.09	o at 1940 p.o.[a]	
Triumfetta sp.	18563	Stems	177	1	0.72	o at 4230 p.o.[a]	o at 196 s.c.[a]
			ULMACEAE				
Celtis occidentalis	16749	Branches	200	1	1.83	o at 5810 p.o.[a]	o at 172 p.o.[a,b]
Ulmus campestris	16420	Branches	141	1	0.58	o at 1320 p.o.[a]	o at 48 s.c.[a]
			UMBELLIFERAE				
Apium graveolens	17553	Seeds	249	1	0.80	o at 4920 p.o.[a]	o at 460 p.o.[a]
Carum carvi	16549	?	200	1	0.27	o at 3680 p.o.[a]	o at 83 p.o.[a]
Carum petroselinum	16515	Seeds	140	1	3.03	o at 5140 p.o.[a]	o at 386 p.o.[a]
Eryngium foetidum	16751	Entire	140	1	3.64	o at 6492 p.o.[b] +++ at 6492 p.o.[a]	o at 408 p.o.[a,b]
Eryngium yuccifolium	16305	Entire	200	1	0.93	o at 1080 p.o.[a] ++ at 1080 p.o.[b]	o at 160 p.o.[a,b]
Pastinaca sativa	16863	Roots	219	1	0.25	o at 3763 p.o.[a,b]	o at 80 p.o.[a,b]
			URTICACEAE				
Humulus americanus	17467	Stems, lvs. & flowers	247	1	0.27	o at 10,860 p.o.[a]	o at 121 p.o.[a]
Urera baccifera	17725	Stems	200	1		o at 4710 p.o.[a]	
			VALERIANACEAE				
Valeriana mexicana	16649	Roots	88	1		o at 2895 p.o.[a,b]	
Valeriana sylvatica	18369	Entire	200	1	1.53	o at 7360 p.o.[a]	o at 200 s.c.[a]
			VERBENACEAE				
Aloysia triphylla	15629	Branches & lvs.	415	1	0.78	o at 8720 p.o.[c,d]	o at 548 s.c.[c,d]
Clerodendrum fragrans var. plenifiorum	18224	Entire	200	1	2.91	o at 7560 p.o.[a]	o at 612 s.c.[a]
Clerodendrum heterophyllum	18547	Branches & roots	200	1	0.25	o at 2085 p.o.[a]	o at 112 s.c.[a]
Clerodendrum siphonanthus	18586	Roots	200	1	0.94	o at 5010 p.o.[a]	o at 316 s.c.[a]
Clerodendrum trichotomum	16917	Entire	160	1	0.46	o at 4244 p.o.[a,b]	o at 97 p.o.[a]
Lantana camara	15121	Flowers & twigs	200	1	0.22	o at 5600 p.o.[a]	o at 28 s.c.[a]
Lantana involucrata	17678	Stems	212	1	0.16	o at 2270 p.o.[a]	o at 50 p.o.[a]
Lippia graveolens	16146	Flowers & lvs.	130	1	3.29	o at 4000 p.o.[a,b]	o at 112 p.o.[a,b]
Verbena litoralis	16203	Entire	61	1		o at 1660 p.o.[a,b]	
			VITACEAE				
Vitis tiliaefolia	17066	Stems & lvs.	200	1	0.20	o at 4880 p.o.[a,b]	o at 40 p.o.[a,b]
Vitis tiliaefolia	18861	Stems	201	1		o at 2080 p.o.[a]	

TABLE 1—*Continued*

Plant	Sample Number	Part Extd.	Amount Extd. g.	Method of Extn.	Yield chloroform Res., %	Antimalarial Water soln.	Activity, mg/kg. Chloroform res.
			ZINGIBERACEAE				
Aframomum melagheta	18916	Fruits	169	1	8.27	0 at 5940 p.o.[a]	0 at 1748 p.o.[a]
			ZYGOPHYLLACEAE				
Guaiacum coulteri	16022 16577	Branches, lvs. & bark	200	1	0.57	0 at 2420 p.o.[a]	0 at 260 p.o.[a]
Guaiacum sp.	16079	Bark	200	1	5.43	0 at 3160 p.o.[a,b]	0 at 556 p.o.[a,b]
Nitraria senegalensis	17588	Roots	260	1	0.15	0 at 3040 p.o.[a]	0 at 60 p.o.[a]
Peganum harmala	15713	Upper	195	1	1.27	0 at 2580 p.o.[a]	0 at 213 p.o.[a]
Porlieria microphylla	17431	Roots	212	1	0.26	0 at 3760 p.o.[a]	0 at 100 p.o.[a]
			UNKNOWN				
"Arnica do Campo"	16324	Branches & lvs.	132	1	0.93	0 at 3110 p.o.[a]	0 at 100 p.o.[a]
"Cassau"	16095	Stems	120	2	0.48	0 at 1800 p.o.[a,b]	0 at 100 p.o.[a]
"Chuchuasi"	16052	Bark	130	2	2.09	0 at 1800 s.c.[a]	0 at 500 p.o.[a] 0 at 480 p.o.[b]
"Chuchuasi"	16057	?	180	1	1.04	0 at 7080 p.o.[a]	0 at 372 p.o.[a]
?	16717	Bark	230	1	0.47	0 at 1710 p.o.[a,b]	0 at 128 p.o.[a] 0 at 256 p.o.[b]
?	16718	Bark	225	1	0.55	0 at 682 p.o.[a,b]	0 at 248 p.o.[a,b]
"Copalchi grueso"	16761	Bark	160	1	0.27	0 at 3123 p.o.[a,b]	0 at 60 p.o.[a] 0 at 120 p.o.[b]
"Copalchi delgado"	16760	Bark	240	1	3.23	0 at 10,082 p.o.[a] 0 at 15,123 p.o.[b]	0 at 134 p.o.[a,b]
?	17736	Roots	232	1	0.88	0 at 3390 p.o.[a]	0 at 520 p.o.[a]
"Iztacpatti"	15961	Roots	200	1	4.61	0 at 8400 p.o.[a]	0 at 58 p.o.[a]
"Lissan Al thaur"	18589	Roots & lvs.	207	1	1.23	0 at 2845 p.o.[a]	0 at 472 s.c.[a]
"Palo santo"	16045	Bark	60	2, 3	0.75	0 at 800 p.o.[a]	0 at 160 s.c.[a]
"Palo de terciana"	18785	Wood	220	1	1.14	0 at 2120 p.o.[a]	0 at 572 s.c.[a]
"Pay-luch"	18870	Stems	200	1	0.86	0 at 4280 p.o.[a]	0 at 412 s.c.[a]
?	17328	Roots	233	1	0.30	0 at 1900 p.o.[a]	0 at 170 s.c.[a]
			CRYPTOGAMAE CHARACEAE				
Nitella monodactylla	16202 17426	Entire	62	1		0 at 3860 p.o.[a]	
			PARMELIACEAE				
Parmelia conspersa	16470	Entire	177	1	0.17	0 at 1890 p.o.[a]	0 at 88 p.o.[a]
			SELAGINELLACEAE				
Selaginella riddellii	17433	Entire	192	1	0.38	0 at 2740 p.o.[a]	0 at 180 p.o.[a]

The Effectiveness of Certain Wood Preservatives in Preventing the Spread of Decay in Wooden Ships[1]

Oswald Tippo,[2] James M. Walter,[3] Silas J. Smucker,[4] and William Spackman, Jr.[5]

INTRODUCTION

At the beginning of the recent war, the building program of the United States Navy called for the construction of thousands of wooden craft. These vessels, varying in length from twenty to one hundred and eighty feet, included such craft as mine sweepers, sub-chasers, P-T boats, patrol craft, net-tenders, sea-going tug boats, aircraft retrievers, aircraft refueling boats, and many others. And it might be added that these ships were fabricated of wood not only because of the shortage of steel, but also because wood has proven to be better adapted to the service requirements of many types of vessels. On the other hand, wood has three shortcomings as far as Naval use is concerned. It is destroyed by marine borers; it is not dimensionally stable, in that it swells and shrinks in response to varying moisture content and may check, warp, twist, or develop other defects; and finally, it rots or decays. In the early days of the war, the Navy sought some treatment which would prevent the development of these defects in wood, and, in addition, it sought a preservative treatment which could be easily applied and hence would not slow down production. The old standbys, such as creosote and zinc chloride, were ruled out for most Naval purposes, since the former is messy, disagreeably odorous, difficult to paint over, and, most important of all, requires pressure methods of application for satisfactory results; while zinc chloride, of course, has the drawback of leaching out readily in water and of corroding action on metal under condi-

[1] The opinions contained herein are those of the authors and do not necessarily reflect the official views of the Navy Department.

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tions of high relative humidity. As a result, the Navy finally turned to copper naphthenate, the chlorinated phenols, and phenyl mercury oleate—three preservatives which had been developed by the oil refining and chemical industries during the previous ten to fifteen years. All of these preservatives contain toxic principles which, it was thought, would discourage borers and wood-rotting fungi. In addition, they may have added to them water-repellents which, it was believed on the basis of experience with these materials in treating millwork, might, to some measure, reduce the rate of water absorption and water loss, and hence minimize swelling, shrinking, and checking.

At the outbreak of the war, little was known about these three preservatives with respect to their effectiveness against marine borers and much less was known about the effectiveness of the water-repellent component, especially on large timbers such as are used in marine construction. Slightly more was known about the efficacy of these preservatives as fungicides, although virtually nothing was known about their performance under marine conditions. As a result, the Navy Department's Bureau of Ships was instrumental in organizing a Wood Section at the Industrial Test Laboratory of the Philadelphia Naval Shipyard, whose function, among other things, it was to conduct extensive investigations on these three wood preservatives. The present paper is the first of a series on the wood decay testing portion of the program at the Laboratory. More specifically this paper deals with an investigation whose object was to determine the effectiveness of copper naphthenate, chlorinated phenol, and phenyl mercury oleate preservatives, in the concentrations specified by Bureau of Ships Ad Interim Specification 52W5 (1), in preventing the spread of decay from infected to sound ship timbers. This investigation was conducted cooperatively by the Industrial Test Laboratory and the USDA Forest Pathology Field Laboratory, Morristown, New Jersey. By the summer of 1943, when the Industrial Test Laboratory began its decay testing program, the Forest Pathology Field Laboratory had already undertaken a preliminary study of the effectiveness of the three preservatives, along with creosote and others, in preventing the spread of a wood-decaying fungus from decaying to surface treated southern yellow pine sapwood (27). Since an account of this preliminary work has never been published, the present paper will summarize the earlier report before the main, Navy-sponsored test is described.

Perhaps a little background on the specific problem dealt with in the present paper will not be out of place at this point. Experience accumulated by the Navy as well as by the exploratory survey of wooden vessels undergoing repair at construction and repair yards and of published reports, conducted in 1942 by the Division of Forest Pathology (17), revealed that extensive repairs because of rot had been necessary in some boats as early

as two or three years after the launching dates. This was expecially true for boats built hastily in wartime. These observations further disclosed that the butt-block joint was the most common locus of decay in hull planking. The indications were, then, that decay damage would occur in the future with greater frequency as contemporary wooden boats aged, especially among the larger craft in which the ceilings are tight and continuous. Furthermore, the decay problem would be intensified when the various craft were removed from service as there is more than a little truth in the Gloucester fishermen's aphorism that an idle year results in as much rot as five years of service.

The question naturally arose as to what measures could be taken to reduce the amount of damage in ships already infected with decay-producing fungi. In the repairing of wooden craft, it is the practice to replace the obviously decaying timbers with new lumber which is either untreated or treated with a wood preservative, while the old, remaining wood may or may not be treated with a preservative. The question arose as to the effectiveness of these various repair procedures, and of the several preservatives, in preventing the spread of decay from timbers which may be decayed. When a boat with decaying timbers has had all the obviously rotten wood removed, it might conceivably be treated in one of the following ways, depending on the amount of time and the equipment available for repairs:

(1) The old timbers surrounding the replaced parts could be brushed with a preservative to inhibit surface development of the decay-producing fungi which may be lurking there, and the new timbers brushed with a preservative to prevent or hinder the spread of any decay, if present in the old timbers.

(2) The old timbers could be brushed with a preservative to inhibit the decay which may be hidden there, and the new timbers pressure treated or treated with preservative by means of the hot and cold bath method for better protection against decay.

(3) The old timbers could be brushed with a wood preservative and the new wood left untreated.

(4) Both old and new timbers might be left untreated.

Accordingly, these four possibilities were kept in mind when the major test herein reported was designed.

MATERIALS AND METHODS

Briefly, the test method involved the preservative treatment of two blocks to which was attached a third or inoculum block containing the wood-decaying fungus, after which the complete assembly was exposed in a humidity chamber. The methods of applying the preservatives were specific for each unit of the studies to be described, and it appears ap-

propriate to present them in the descriptions of the specific tests. A detailed account of the generalized features of the test procedure follows.

Description of test panel.—The complete test panel consisted of three southern yellow pine sapwood blocks, simulating a butt-block assembly, as shown in Figure 1 (a drawing of the test panel) and Figure 2 (a photograph of the test panel). Each panel was composed of a large block, measuring 7/8″×5″×6″, and attached to this were two small blocks, measuring 7/8″×5″×3″. One of the latter served as the source of the decay organism, and, as can be seen in Figures 1 and 2, was in a position to permit the test

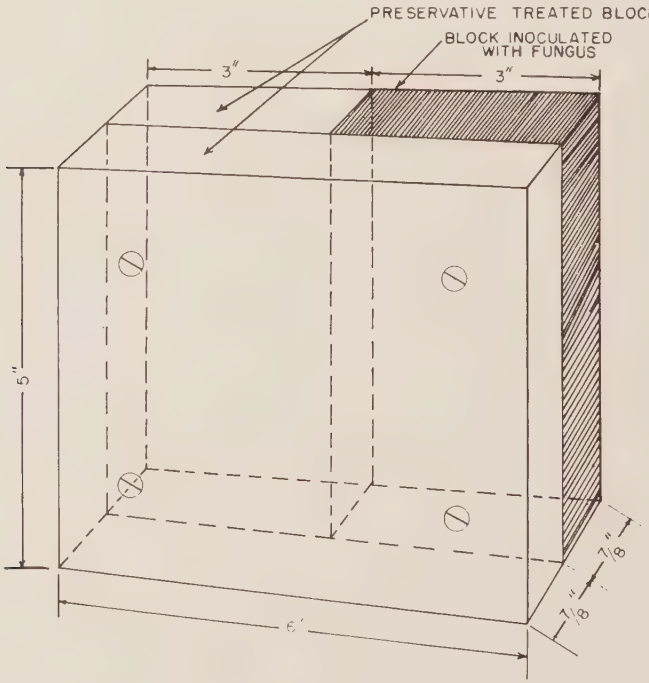

FIG. 1. Drawing of the test panel showing the relative positions of the large, and small, and the inoculum blocks.

fungus to penetrate the end grain of the small block and the side grain of the large block. Four holes were drilled and then countersunk in the large block. These holes were made at this stage so that no untreated surfaces would be exposed, as would be the case if the holes were drilled after the block had been treated. At a later stage the large block was attached to the two small ones by means of four screws.

Preparation of the inoculum block.—A culture of *Poria xantha* (Fries ex Lind) Cooke, a rapid wood-destroying fungus of a species frequently isolated from decaying boat timbers (12), was secured from the Division of

Forest Pathology, USDA, Beltsville, Maryland, for use in these tests (isolate #213—boat series). In order to increase the quantity of the fungus, transfers were made, as the inoculum was needed, from this original culture to Petri dishes containing 2 per cent malt agar.

The inoculum blocks were first soaked in water for an hour. At the same time cracked corn was given similar treatment. The blocks and corn were then put in galvanized cans in such a way that each of the blocks was surrounded by a layer of the corn. After the cans had been filled, the rims of the covers were lined with nonabsorbent cotton, and the covers were forced on the cans, making effective seals. The cans and their contents were then autoclaved at a steam pressure of 15 pounds for three and one-half hours. This autoclaving was repeated after an interval of two or three days in order to destroy the vegetative cells produced by spores which might have

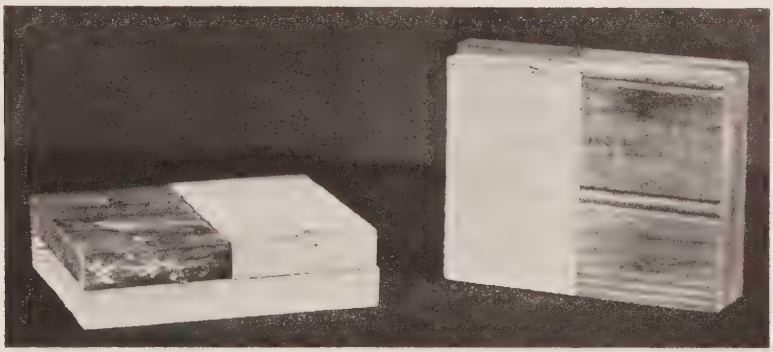

FIG. 2. Photograph of two of the test panels. The darker small blocks are the inoculum blocks. The white patches on the sides and on the top of the inoculum block to the left are mycelium of the fungus *Poria xantha* which in this case was growing out of the wood. It is this mycelium growing out from the contact face of the inoculum block which infects the other blocks of the assembly.

survived the first day's heating. When the cans had cooled, a piece of agar with the test fungus growing on it was transferred from a culture to the center of the corn and wood contents of each can through a hole in the top of the can. This orifice was then closed by replacing the cotton plug.

These cultures were allowed to incubate at approximately 80° F. for about 12 weeks. During this time the fungus usually had spread throughout the corn, the blocks were usually coated with a mat of fungus mycelium and the blocks themselves were infected with the decay organism as evidenced by marked softening of the wood. The excess fungus was scraped off the blocks and the latter were ready for treatment or attachment to the test panels.

Exposure in the humidity chamber.—After assembly, the test panels were placed on their edges upon glass rods in a humidity chamber, as shown by

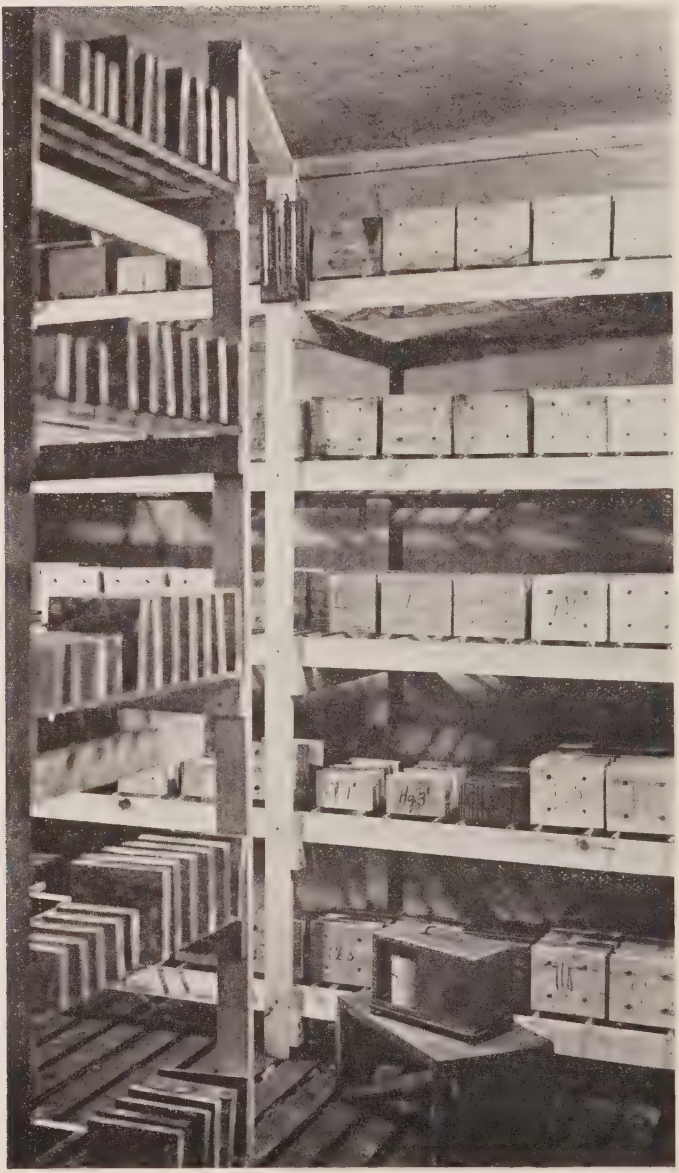

FIG. 3. Photograph of the interior of the humidity chamber at the Morristown Field Laboratory. The test panels are shown on their edges and supported by glass tubing.

Figure 3. In the humidity chamber or "rot cellar" the temperature was kept between 75° and 85° F. by means of the heat radiating from electric light bulbs. The relative humidity was maintained at 90 to 94 per cent by spraying the walls, the shelves, and the panels twice a day, using nozzles which divided the water into small droplets. To make certain that all the panels received approximately equal quantities of water, the twenty or twenty-five panels of like treatment were distributed equally in vertical line on the five shelves and, furthermore, the blocks were rearranged monthly by rotation from upper to lower shelves and from front to back on the shelves. In this fashion, the panels were maintained at a moisture content of 50 to 80 per cent (on the basis of the oven-dry wood), determined from time to time by means of weighing some blocks exposed in the chamber for this purpose.

Observations on the panels for the presence of decay.—In examining the panels, color changes and softening were taken as indications of rot. Consequently, the presence of these signs of decay on a given block was considered as evidence that the particular treatment had failed on that block. However, to aid in differentiating among the various degrees of failure and to allow for biometrical analysis in case it were needed, a numerical scoring method was employed to evaluate the degree and extent of decay. This scoring method was first used by the Forest Pathology Field Laboratory, Madison, Wisconsin (24), and subsequently was modified by the staff of the Morristown Forest Pathology Field Laboratory. In its final form, the method involves the use of the numbers 1 to 10 in representing the extent or the area of decay. For example, if a piece were one-tenth decayed it would receive a rating of 1; if fourth-tenths decayed, a rating of 4, etc. Likewise for the degree or stage of decay, numbers were assigned according to the following schedule:

0 = no decay
2 = incipient decay—the principal evidence being depletion of wood color or graying.
4 = slight decay color changes plus first stages of recognizable softening.
6 = moderate decay—marked color changes and easily recognizable softening.
8 = much decay—shrinking and checking easily recognizable.
10 = destroyed—wood broken down to small bits by cubical checking or to pulp by fiber separation.

Finally, the product of the two numbers, i.e., one representing the extent and the other the degree of decay, was taken as the index of decay on the whole surface. For example, if one-half of a given surface exhibited graying, then it would be rated 5×2 or 10. Or to use a more complex example, four-tenths of the block might show graying, two-tenths might be shrunken, and another tenth broken down. This block would be rated $4 \times 2 + 2 \times 8$

+1×10 or 34. Destruction of the entire block would lead to a rating of 10×10 or 100. In employing this method, the only faces scored were the contact faces, that is, those in contact with other blocks. An exception to this was made in the case of the inoculum blocks, for which both inner and outer faces were graded.

To test the reliability of the method, several blocks were scored independently by four different individuals with the result that a fair degree of reproducibility was achieved. However, it should be emphasized that this scoring method is intended only to differentiate among the various degrees of failure. The important consideration is whether a given block shows *any* decay, and of course this was determined with relative ease and with a considerable degree of certainty by visual observation and by probing the blocks at the time of the final inspection. After this the blocks were split open to verify the results obtained by the surface explorations. In the study of the split surfaces, observations of gross characteristics of decay, such as color and texture, were supplemented by microscopical examination. In this connection, Hubert's thorough treatment of the diagnosis of decay in wood (20) served as a guide. So far as color is concerned, evidence of graying or blackening was noted, as well as the presence of decay lines or zone lines (Figure 7). With reference to texture, any softness, brashness or lack of elasticity was noted. To test for softness, the bit of a screw-driver was used. Slivers of wood were pryed up with the blade of a knife to see if the splinters were elastic or brash. Portions of a number of the blocks were examined with the microscope, especially the panels which had been treated with phenyl mercury oleate and those panels which possessed discolorations which might be confused with metal effects, water core, and blue staining. In the examination with the microscope, the presence of bore holes in the cell walls was taken as an indication of decay. If at the conclusion of the probing and the examinations, both gross and microscopical, there still remained any doubt about the presence of decay, the panel in question was given the benefit of the doubt and hence marked sound. In other words, the methods employed in the diagnosis of decay were conservative.

PRELIMINARY TEST OF SEVERAL PRESERVATIVES APPLIED BY QUICK DIPS

As indicated in the Introduction, the Forest Pathology Field Laboratory at Morristown, New Jersey had undertaken a preliminary test of several preservatives before the Industrial Test Laboratory entered the decay testing program in the summer of 1943. Since this earlier work, which has not been published but has been summarized in an office report (27), was the basis for the logical planning of the major study to be re-

ported, it appears in order to give at this point a fairly complete account of this preliminary study.

The procedure described under Materials and Methods was devised in this earlier study. The wood used in the test panels was well-seasoned southern yellow pine sapwood having at the time of treatment an average air-dry moisture content of 10.4 per cent. Seven preservatives, as follows, and the nontreated controls constituted the units of the test:

1. Celcure, a proprietary preservative containing six per cent each of copper sulphate and sodium bichromate in aqueous solution of acetic acid.
2. Phenyl mercury oleate (five tenths per cent in mineral spirits).
3. Pentachlorophenol (five per cent in mineral spirits).
4. Copper naphthenate (as supplied by dealer, in concentration understood to contain 2 to 3 per cent copper).
5. Copper ammonium naphthenate (30 per cent copper naphthenate diluted two parts to one part ammonia water, reducing copper content to approximately 2 per cent).
6. Creosote (A.W.P.A. Creosote Oil grade #1).
7. BSE (four tenths per cent copper in mineral spirits as supplied by the Batelle Memorial Institute, Columbus, Ohio).
8. Untreated checks.

Treating procedure —The blocks were divided into two series and treated in units of 25 for each of the two sizes and for each of the seven preservatives. In Series 1 the blocks were immersed in the preservative for 15 seconds. After removal from the treating solution, the blocks were placed so as to permit drainage of the solution from their surfaces for approximately 5 minutes after which they were stacked for 9 days to permit evaporation of some of the carrier oil. The blocks in Series 2 received a 3-minute

TABLE 1. *Average Retention of the Preservatives by Southern Yellow Pine Blocks Dipped for 3 Minutes and Dried for Twenty-Four Hours.*

Preservative	Large block $5'' \times 6'' \times \frac{7}{8}''$	Small block $3'' \times 5'' \times \frac{7}{8}''$
	Pounds per Cu. ft.	Pounds per Cu. ft.
Celcure	2.2	3.2
Phenyl mercury oleate	1.7	1.6
Pentachlorophenol	1.7	2.1
Copper naphthenate	1.2	1.6
Creosote	1.6	2.9
BSE	1.4	2.3

dip. After treatment they were stacked and some of the solvent was permitted to evaporate for 24 hours, after which they were weighed to determine the retention of the preservatives. Data showing retention of

preservatives after the solvent had been permitted to evaporate for 24 hours are presented in Table 1. It is noteworthy that the retentions per cubic foot are, in five of the six treatments, considerably higher for the small blocks than for the large blocks.

Conditioning of surface-treated wood.—The unassembled treated blocks of both series were placed in incubators maintained at approximately 26° C. Twice daily, they were given a fine mist spray for the purpose of raising the moisture content of the wood to a point favorable for the development of decay organisms. After a month, the inoculum blocks were attached to the surface-treated pieces of both series, and all were exposed in the chamber shown in Fig. 3.

Evaluation of decay.—As the experiment progressed it became evident that decay was developing rapidly in the cupric chromate and nontreated assemblies, and to a lesser extent in the remaining blocks. Four months after attaching the inoculum blocks, the entire lot of cupric chromate and non-treated assemblies, and five assemblies selected at random (two treated blocks per assembly) from each of the remaining treatments were removed from the humidity chamber and examined for decay. Results of this examination are summarized in Table 2.

Six months after attaching the inoculum the remaining blocks were removed and examined for decay. Results of this examination are summarized in Table 3.

TABLE 2. *Per Cent of Surface-Treated Southern Yellow Pine Blocks with Decay after Exposure to Poria xantha for 4 Months.*

Preservative	Per cent of blocks with decay		
	15-second dip	3-minute dip	Average of both dips
Celcure[a]	100	100	100
Phenyl mercury oleate[b]	0	20	10
Pentachlorophenol[b]	0	10	5
Copper naphthenate[b]	70	50	60
Copper ammonium naphthenate[b]	0	—	—
Creosote[b]	0	20	10
BSE[b]	100	100	100
Non-treated assemblies[a]	— 100	—	—

[a] Figures are for 50 blocks, i.e. 25 large and 25 small.
[b] Figures are for 10 blocks, i.e. 5 large and 5 small.

Soon after the blocks had been placed in the humidity chamber, *Poria xantha* and several molds were noted growing on the surface of some of the blocks. When the blocks were disassembled for final examination, it was found that *Poria* had formed vigorous "fans" between some of the treated

TABLE 3. *Per Cent of Surface-Treated Southern Yellow Pine Blocks with Decay after Exposure to Poria xantha for 6 Months.*

Preservative	Per cent of blocks with decay		
	15-second dip	3-minute dip	Average of both dips
Phenyl mercury oleate	39[a]	55	47
Pentachlorophenol	40	70	55
Copper naphthenate	73	70	71
Copper ammonium naphthenate	68	—	—
Creosote	63	60	61
BSE	100	100	100

[a] This figure is for 38 blocks; all others for 40.

blocks. A summary of the results of the examination of the blocks after six months' exposure, in terms of average decay ratings arrived at by the product method, is presented in Table 4.

TABLE 4. *Summary of Average Decay Ratings of Surface-Treated Southern Yellow Pine Exposed to Poria xantha for 6 Months.*

Preservatives	Large Block	Small Block		Average of Faces of Both Blocks	Inoculum Block	
	Inner Face	Inner Face	End		Inner Face	Outer Face
	15-second dip					
Phenyl mercury oleate	2	1	0.2	1.5	34	23
Pentachlorophenol	6	1	1	3.5	38	28
Copper naphthenate	23	14	5	18.5	51	33
Copper ammonium naphthenate	4	2	1	3.0	50	33
Creosote	4	3	0	3.5	52	29
BSE	39	34	12	36.5	55	28
	3-minute dip					
Phenyl mercury oleate	5	5	1	5.0	31	23
Pentachlorophenol	5	3	4	4.0	45	24
Copper naphthenate	15	6	2	10.5	62	27
Creosote	12	6	0.1	9.0	60	29
BSE	45	21	30	33.0	60	30
	Averages for both dips					
Phenyl mercury oleate	3.5	3.0	10.6	3.3	32.5	23.0
Pentachlorophenol	5.5	2.0	2.5	3.8	41.5	26.0
Copper naphthenate	19.0	10.0	3.5	14.5	56.5	30.0
Creosote	8.0	4.5	0.05	6.3	56.0	29.0
BSE	42.0	27.5	21.0	34.8	57.5	29.0

Discussion of results of quick-dip test.—The data presented in Tables 2, 3, and 4 clearly indicate: (1) that southern yellow pine surface-treated with Celcure was no more or little more resistant to *Poria xantha* than the

nontreated wood; (2) that BSE had only slight effect in retarding this decay; (3) that copper naphthenate was intermediate in effectiveness; (4) that creosote and copper ammonium naphthenate were fairly effective on side grain, and on end grain the creosote was slightly more effective than any other; and (5) that pentachlorophenol and phenyl mercury oleate imparted the most resistance to infection by *Poria xantha* through side grain.

Copper ammonium naphthenate may be eliminated from any list for consideration of utilization on wood that is to be painted and perhaps further on the basis of handling properties because of the following difficulties: (1) the preparation thickens on standing and must be diluted with ammonia water before use, the latter proving objectionable to the operators; (2) it leaves a thick, uneven coating on the wood surface—this is at first slimy but gradually becomes waxy. These difficulties seemed insurmountable and, with the knowledge that they had been encountered in shipyards, the chemical was omitted from the 3-minute treatment. Creosote, despite its reasonably good performance in this test, can hardly be considered for use on timbers for interior construction in boats because the creosoted lumber gives off objectionable fumes for a long period, and the creosoted surface cannot be painted without extra expense.

The advantage of pentachlorophenol and phenyl mercury oleate over other preservatives is made clear by both methods of presenting the results, (1) the proportion of blocks infected as shown in Table 3, and (2) the ratings by the product method as shown in Table 4. The latter figures are, in one sense, a more directly applicable evaluation because they take in account the number of infections, the extent of invasion, and the promptness of infection as reflected in the degree of deterioration. Since they use all the available data, they probably are more reliable and reproducible than the ratings obtained by the method of Table 3. There is some indication of this in the figures presented, since in Table 3 for the 15-second dip creosote and copper naphthenate appear decidedly inferior to the phenyl mercury oleate and chlorinated phenol treatments, while for the 3-minute dip, which should have rated the treatments in similar order, no inferiority is indicated. In Table 4 there is less inconsistency between the 15-second and 3-minute dips, the phenyl mercury oleate and chlorinated phenol treatments averaging better on side grain than either copper naphthenate or creosote in both types of dips. However, the comparison between creosote and copper naphthenate in Table 4 is less consistent than in Table 3.

Conclusions based on the preliminary test.—

1. Of seven preservatives tested, phenyl mercury oleate (five tenths per cent) and pentachlorophenol (five per cent) applied as quick dips were approximately equal in effectiveness in protecting southern yellow pine from decay by *Poria xantha*. Creosote and copper naphthenate allowed a con-

siderable number of infections and cupric chromate, as furnished by the manufacturer, had no apparent value in this test.

2. The 3-minute dip appeared no more effective than the 15-second dip in affording protection against decay.

3. In general, the preservatives appeared to afford better protection against decay at the end grain than at the side grain, the small blocks in which the end grain exposure occurred showing a higher retention of preservative per unit volume than the large blocks having the side grain contact. This has some bearing on the use of timber in construction, since the untreated centers exposed in cutting and fitting would ordinarily be end grain and must depend for their protection on swabbing with a preservative on the job.

Soil exposure tests.—At the time the panels were prepared for this preliminary test, additional sets of twenty-five large blocks ($6'' \times 5'' \times \frac{3}{4}''$) were treated by means of the three-minute dip with each of the following preservatives: copper naphthenate, pentachlorophenol, phenyl mercury oleate, creosote, and Celcure. They were then exposed in the soil by the Division of Forest Pathology at the Harrison Experimental Forest, Saucier, Mississippi. At the end of a two-year exposure period, many of the blocks had been damaged by termites. The following figures indicate the number that showed some decay in that group of blocks which escaped termite damage, or in which the termite damage was slight: creosote, 9 blocks decayed out of 23; Celcure, 1 out of 19; copper naphthenate, 1 out of 25; pentachlorophenol, 1 out of 2; and phenyl mercury oleate, 2 out of 2.

Dr. A. F. Verrall of the Division of Forest Pathology was in charge of the soil exposure test at Saucier, and came to the following conclusions:

1. Celcure and copper naphthenate gave good protection against decay.

2. Creosote gave moderately good protection against decay for $1\frac{1}{2}$ years, but at the end of two years almost two thirds of the creosoted stakes without termite damage showed decay. The creosoted stakes failed through the action of fungi and not termites.

3. So many of the stakes treated with pentachlorophenol and phenyl mercury oleate were heavily attacked by termites early in the test that little useful information on decay resistance of the wood treated with these two chemicals was secured. It was surprising that a number of stakes treated with pentachlorophenol and phenyl mercury oleate and heavily termite penetrated, had little evident decay, the wood exposed by the termites being bright and normal appearing. This was not true in the untreated stakes and, consequently, lack of decay cannot be laid solely to the termites keeping ahead of decay advance.

At the end of three and one half years of exposure, only a few of the blocks were untouched by termites, but the following figures were obtained on the number of decayed blocks among those undamaged by

termites: creosote, 6 blocks decayed out of 6; Celcure, 0 out of 6; copper naphthenate, 0 out of 6; pentachlorophenol, 2 out of 2; and phenyl mercury oleate, 2 out of 2.

These results are far from conclusive with respect to the relative effectiveness of the preservatives against decay because of the complication introduced by the termites.

A duplicate set of 25 blocks with each treatment was exposed in soil at Morristown, N. J., and no termite injury occurred. After $3\frac{1}{4}$ years, including most of four summers, visual decay ratings were made in which 1 denoted very slight decay, 2 slight, 3 moderate, 4 heavy, 5 very heavy, and 6 destroyed. The average ratings on this scale were:

Creosote	2.1	Pentachlorophenol	4.2
Copper naphthenate	3.0	Phenyl mercury oleate	4.4
Celcure	4.2	Untreated	4.8

The tests on dip-treated pine from the same original source can be summarized as follows:

	Inoculated with *Poria xantha*	In soil at Saucier, Miss.	In soil at Morristown, N. J.
Creosote	Good	Poor	Very good
Copper naphthenate	Intermediate	Very good	Good
Celcure	Poor	Good	Intermediate
Pentachlorophenol	Very good	Poor	Poor
Phenyl mercury oleate	Very good	Poor	Poor

There is so much disagreement among the three different tests on the same treated material, and so few of the blocks treated with pentachlorophenol and phenyl mercury oleate escaped termite damage in the Saucier test that it would be unsafe to generalize from them. When wood is impregnated as it should be for use in soil, pentachlorophenol is known to give effective protection. Caution is suggested in any attempt to use the results obtained in the test involving exposure to the single fungus in the humidity chamber to predict the performance of these preservatives in service, especially in situations involving contact with soil.

STUDY OF THE EFFECTIVENESS OF THE SPECIFIED PRESERVATIVES IN PREVENTING THE SPREAD OF DECAY FROM INFECTED WOOD

The success of the technique used in the preliminary experiment offered the encouragement that a practical study of the questions then confronting the Bureau of Ships concerning wood preservatives could be carried out in a few months.

The wood preservatives tested in this study conformed to the requirements of Bureau of Ships Ad Interim Specification 52W5 (INT) (1), including the requirement that the nonvolatile components (water-repellents and toxic ingredients) shall total at least 1.0 pound per gallon of solution. The preservatives were of the following three types:

1. Type A, copper napthenate, containing 2 per cent metallic copper (0.15 pound or 68 grams of metallic copper per gallon of solution).

2. Type B, chlorinated phenols, containing 5 per cent (0.35 pound or 159 grams per gallon of solution) of chlorinated phenols of which 3 per cent (0.21 pound or 95 grams) was pentachlorophenol. The remaining 2 per cent (0.14 pound or 64 grams) was chlororthophenylphenol, tetrachlorophenol or mixtures of the two.

3. Type C, phenyl mercury oleate, containing 0.5 per cent (0.035 pound or 16 grams per gallon of solution) of phenyl mercury oleate.

In addition to the above, two mineral spirit dilutions of Type C preservative were tested:

1. Type C, containing 0.1 per cent phenyl mercury oleate.

2. Type C, containing 0.2 per cent phenyl mercury oleate.

Treatment procedure.—The actual repair problems of the boat shop were constantly in mind during the planning of the present investigation. When a boat with decaying timbers has had all the obviously rotten wood removed, it might conceivably be treated in one of the four ways already described in the Introduction. These four situations were in mind when the test procedure was designed. Accordingly, as indicated in Table 5, sets of twenty unassembled large, small, and inoculum blocks were brushed with copper naphthenate, chlorinated phenols, and phenyl mercury oleate. Other sets were given the hot and cold bath treatment which consisted of steeping the pieces (other than inoculum blocks) for four hours in the preservative heated to 140° F. and then allowing the pieces to remain overnight in the solutions while the latter cooled. The inoculum blocks for combination with the hot and cold treated blocks were brushed with the appropriate preservatives. For the third type of combination the inoculum blocks were brush-treated with each of the three types of preservative but the other blocks making up these panels were left untreated. Finally, the control set consisted entirely of untreated blocks.

Since there was some basis for the belief that the 0.5 per cent phenyl mercury oleate might be unnecessarily high in concentration, particularly with the absorptions achieved by the hot and cold bath method, other sets were given the hot and cold bath treatment with 0.1 per cent and 0.2 per cent phenyl mercury oleate.

After treatment, all the blocks were air-dried and then the three blocks of each panel were assembled by means of four screws.

The test panels were exposed in the chamber for a year and seven months. The first examination was made after six months. Since at that time the fungus in many of the inoculum blocks seemed to be inactive, new inoculum blocks, treated as before, were attached to the panels and the assemblies returned to the humidity chamber for re-exposure. After six months, the panels were disassembled and observations were made for the

presence of decay. After the examination, fresh inoculum blocks treated in the appropriate manner were affixed to the panels and the assemblies put back in the humidity chamber to continue the exposure for seven more months before the final decay readings were made. The extent and degree of decay in these inoculum blocks were recorded before they were treated and attached.

RESULTS

Table 5 is a summary of the data obtained after the year and seven months of exposure. The percentage of the blocks in each set that developed any decay is recorded opposite a tabular description of the treatment received by the set. Averages of the decay ratings obtained by scoring the panels in each of the various sets are also brought together in Table 5. It will be noted that in the table the ratings assigned to the inoculum blocks both before attachment and after exposure, are also recorded.

TABLE 5. *Percentage of Blocks with Decay, and Averages of the Decay Ratings Assigned to the Test Panels after a Year and a Half of Exposure.*[a]

Large and Small Blocks		Inoculum Blocks		Percentage of Blocks with Decay		Average Decay Ratings					
						Large Blocks	Small Blocks	Fresh Inoculum Blocks as Attached in 12th Month		Inoculum Blocks as Disassembled in 19th Month	
Preservative	Application	Preservative	Application	Large Blocks	Small Blocks			Inner Face	Outer Face	Inner Face	Outer Face
Type A[b]	Brush	Type A	Brush	30	30	10	7	19	12	34	31
Type B[c]	Brush	Type B	Brush	0	0	0	0	29	20	29	23
Type C[d] (.5%)	Brush	Type C (.5%)	Brush	0	0	0	0	24	15	27	13
Type A	Hot and Cold	Type A	Brush	15	10	1	1	26	11	41	26
Type B	Hot and Cold	Type B	Brush	0	0	0	0	21	9	31	25
Type C (.5%)	Hot and Cold	Type C (.5%)	Brush	5	0	1	0	22	7	27	16
Type C (.1%)	Hot and Cold	None	None	35	25	7	4	21	17	41	38
Type C (.1%)	Hot and Cold	Type C (.1%)	Brush	60	45	8	9	15	9	35	27
Type C (.2%)	Hot and Cold	None	None	60	65	14	13	18	11	38	36
Type C (.2%)	Hot and Cold	Type C (.2%)	Brush	45	50	8	6	17	13	36	27
None	None	Type A	Brush	55	50	17	16	25	13	37	22
None	None	Type B	Brush	30	25	6	5	32	17	41	24
None	None	Type C (.5%)	Brush	20	20	6	5	25	15	32	20
None	None	None	None	90	100	28	33	24	18	43	28

[a] Each figure is based on 20 blocks.
[b] Copper naphthenate (2% copper).
[c] Chlorinated phenols (5%).
[d] Phenyl mercury oleate (0.5%).

Examination of Table 5 reveals that no decay developed in the sets in which the large and small blocks were given the hot and cold bath or the brush treatment with chlorinated phenols. The same is true of the similar sets treated with phenyl mercury oleate, except that one infected block occurred in the hot and cold bath set. With reference to copper naphthenate, 15 per cent of the panels given the hot and cold bath treatment de-

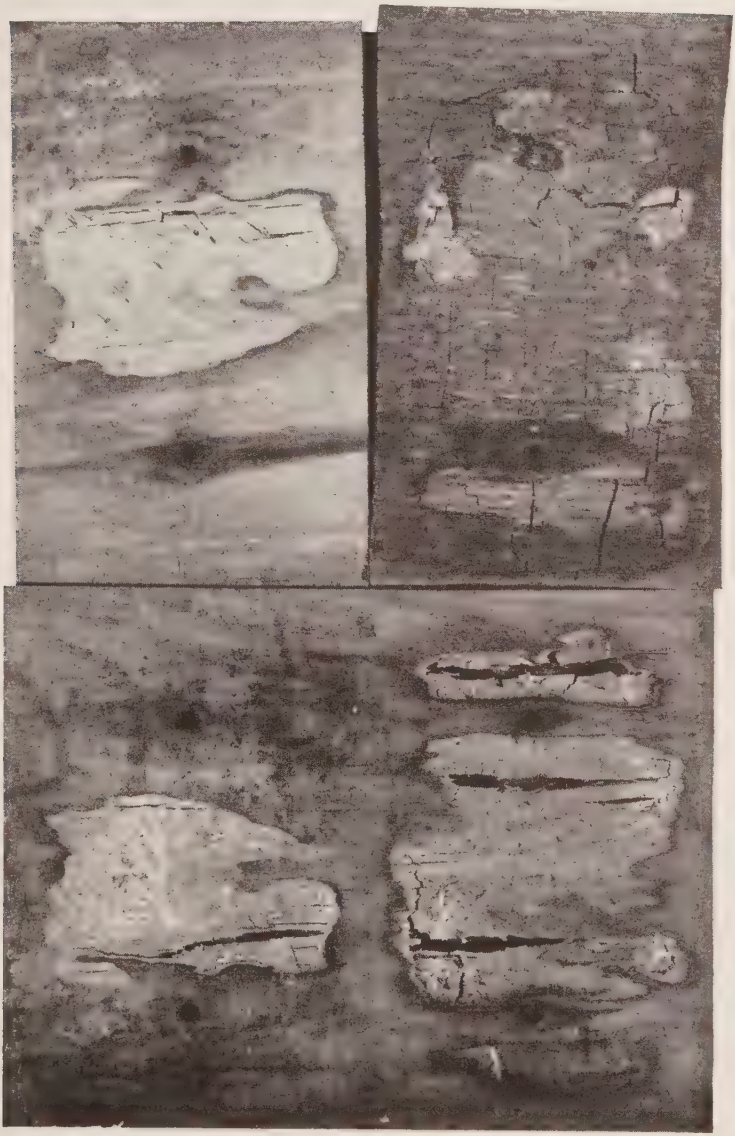

FIG. 4. Photograph of a test panel in which all three blocks were brushed with copper naphthenate. All three blocks show the usual signs of decay plus the presence of white mycelium in some of the decayed areas. Note that the decay patterns on adjacent blocks correspond in outline. This emphasizes the fact that if one faying surface becomes decayed, the other will be infected too.

cayed, while roughly one-third of the brushed set showed rot. In the sets in which the inoculum blocks were brushed but in which the large and small blocks were left untreated, the chlorinated phenols and phenyl mercury oleate were superior to copper napthenate, which permitted about 50 per cent decay. The four sets treated with low concentrations of phenyl mercury oleate allowed from 25 to 65 per cent decay. All of the untreated panels decayed. Figures 4 to 8 are photographs of decaying panels and a few protected panels.

Absorption records were not kept on the treatment of the blocks but similar panels treated in the same way with the same three preservatives yielded the absorptions recorded in Table 6.

TABLE 6. *Average Absorptions of Solutions Achieved by Brushing and With the Hot and Cold Bath Method.*

Preservative	Absorptions in lbs./cu. ft.	
	Brush	Hot and Cold Bath
Copper naphthenate	1.1	9.8
Chlorinated phenols	1.1	9.8
Phenyl mercury oleate	1.2	12.1

DISCUSSION

Before proceeding to a detailed discussion of the various conclusions which can be drawn from this investigation, attention should be given to a consideration of the validity of the method used in this test to evaluate the effectiveness of the preservatives, and brief attention should also be devoted to some miscellaneous observations made during the course of the investigation.

In evaluating the significance of the results as set forth in this report, certain obvious limitations of the test should be considered. One of these limitations is that only one decay-producing organism was employed as a test fungus, while, of course, wood decay is caused by a number of fungi. For example, in the survey already mentioned (12, 17) it was found that more than a dozen xylophagous fungi were active in boats, although the bulk of the organisms belong to five species. It would be desirable to use all or, at least, most of these fungi in a test of this sort because the various organisms differ, among other things, in the rate of the deterioration they produce and in their susceptibility to the various toxicants. However, the mere addition of a single fungus to this test would have required 260 more panels, not to mention more cans for culturing inoculum blocks, more humidity chamber space, etc. Consequently the practical expedient was to

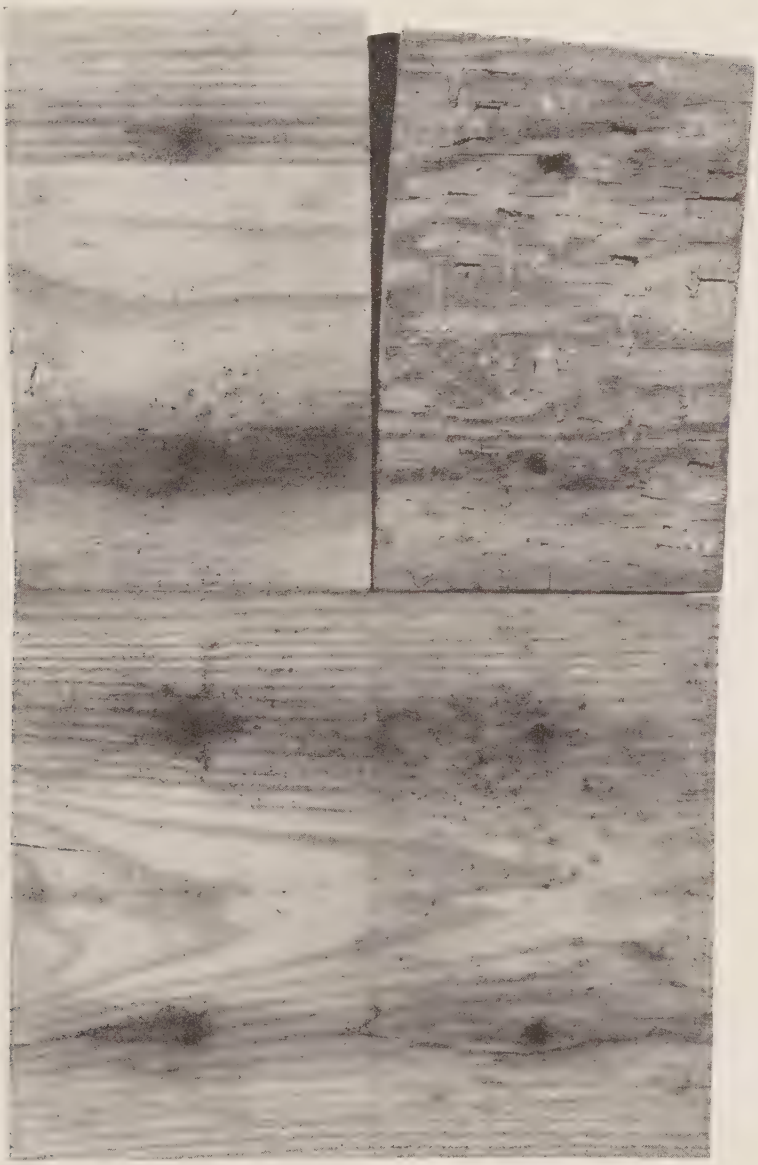

FIG. 5. Photograph of a test panel in which the large and the small blocks were treated with chlorinated phenols by means of the hot and cold bath method and in which the inoculum block was brushed with the same preservative. The large and small blocks are adequately protected against decay. The indentations and grooves on the decayed inoculum block serve to bring out its soft texture. The dark discolorations around the screw-holes of the large and small blocks were caused by the solubilization of the metal from the screws.

choose one of the more rapid wood-destroyers of common occurrence in decaying wood, especially boat wood. *Poria xantha* is such an organism.

Another aspect which might possibly be considered a limitation of the test is the fact that the amount of decay was not determined by the weight-loss method. It is customary in laboratory tests to condition the test panels in a humidity control room before and after exposing them to the ravages of the fungus and then to weigh them. The calculated weight-loss is considered to be an index of the amount of decay. However, since the primary interest here is to determine if the preservatives permit any decay, this was determined nearly as easily and accurately by examination as by the weight-loss method. In passing, it may be remarked that the use of loss in specific gravity as a criterion of decay is not without its pitfalls, as it has been shown by Scheffer (29) and by Scheffer, Wilson, Luxford, and Hartley (30) that considerable loss of strength can occur as a result of decay before there is an easily measurable reduction in specific gravity. Another objection to the weight-loss method of measuring decay is the fact that errors arise due to the further volatilization of the preservatives or solvents. It is also true that, historically, the development of the weight-loss method has been linked with the use of small wooden test blocks in which it is difficult, if not impossible, to evaluate the amount of decay by pricking or some such method. In larger blocks, such as those used in the present test, the difficulties are not so great. Despite the putative limitations of the test as set forth above, it may be said that the test panels simulated butt-block joints and the conditions under which they were placed offered a very close approximation to actual service conditions in that the blocks were exposed to the leaching action of the spray water and the humidity chamber was large enough to permit volatilization of the toxicants, without vapor concentrations likely to interfere with fungi. In these features reposed the outstanding advantages of the method used. At the same time the test allowed a certain degree of desirable acceleration. Certainly for the practical objectives in view this technique for testing wood preservatives has much to recommend it over the standard Petri dish method with its complete divorce from wood in the test procedure, or over the Kolle flask or glass jar methods, employing small pieces of wood.

Despite the fact that conditions in this test were made to duplicate service conditions as closely as possible, no attempt should be made to use the results in drawing definite conclusions on the length of time that the several preservatives will protect boat timbers against decay under the diverse conditions of service. There are too many variables in the environment to permit such generalizations. Temperature, ventilation, and water may be cited as a few of the factors which have a bearing on the progress of decay. Only adequately kept service records can supply this vital information on the service life of treated boats and boat parts. On the other hand,

FIG. 6. Photograph of a test panel in which the large and small blocks were treated with phenyl mercury oleate by the hot and cold bath method and in which the inoculum block was brushed with the same toxicant. The large and small blocks are sound, although the inoculum block is decayed. The black areas and the black lines are molds which flourish on the panels treated with phenyl mercury oleate.

it is believed that the test conditions do permit a comparison of the effectiveness of the preservatives used, of the two methods of application, and of the several repair procedures. Further, it is the opinion of the authors that the results are good evidence that brush applications of chlorinated phenols will protect boat timbers from decay for a sufficient length of time to warrant their recommentation for use in construction and repair yards where more thoroughly impregnated lumber is not available.

Turning now to the miscellaneous observations made during the course of the investigation, attention is directed to the fact that more large blocks decayed than small ones, suggesting that there has been more side penetration than end penetration by the decay organism. It will be recalled that the placement of the three blocks is such that the inoculum block presents its broadside to the face of the large block and that the inoculum and small blocks contact by means of their end grain. In untreated wood, fungi ordinarily penetrate more readily through end grain than side grain surfaces. The apparent explanation for the penetration differential in this experiment is partly the small area of end surface exposed, but mostly that the preservative is absorbed to a greater depth at the end than it is at the sides and therefore the protection at the end is better.

Another observation made was that phenyl mercury oleate is conspicuously poor in discouraging the growth of surface molds on the test panels. On the other hand, the panels treated with chlorinated phenols were outstandingly free of mold growth, while those panels to which copper naphthenate was applied were intermediate in this respect. Figure 6 shows a black mold on a representative panel treated with phenyl mercury oleate. This same tolerance of molds for phenyl mercury oleate has been reported by Shanor (32), Hubert (21), and Goodavage (16) and for ethyl mercury salts by Scheffer and Lindgren (31) and by Verrall (34). It was also noted in the present study that phenyl mercury oleate produces, especially in the hot and cold bathed panels, a condition which, if examined superficially, might be confused with decay. The wood in such panels may become gray, lose some of its elastic nature, and at times may contain larger quantities of water than some of the adjacent wood. In appearance this condition is quite different from stained wood or that found near the screws. No explanation can be offered at this time for this peculiar condition.

Another striking phenomenon observed was the manner in which the green color in the panels treated with copper naphthenate was apparently removed by the test fungus. Figure 8 is a photograph of a panel with one of these decolored zones surrounding the mycelium of the fungus. Similar observations have been made by Weston (37), by Marsh et al. (25), and by Southam and Ehrlich (33). Weston states that the fungi reduce the copper content below the lethal minimum essential for protection. A sample of the

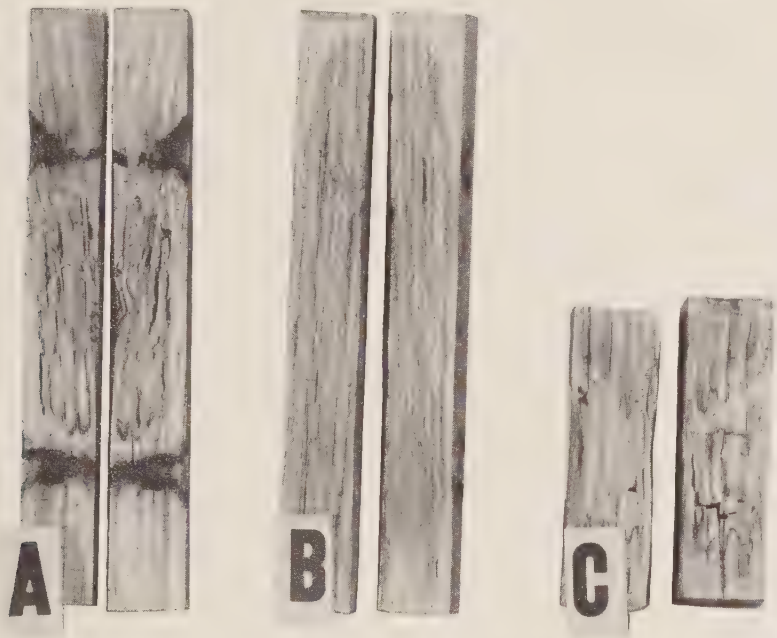

FIG. 7. Photograph of three of the panels which have been split open. In A, note that the area of decay on the surface is small, yet the amount of decay below the surface is extensive. The decayed regions are discolored and the wood in them is soft and punky. The black regions are screw holes. In B, all of the interior of the panel has decayed, leaving nothing but a shell of sound wood at the surface which is broken here and there, producing localized islands of surface decay. In panel C, the median region is badly decayed and this region is bounded by black decay lines.

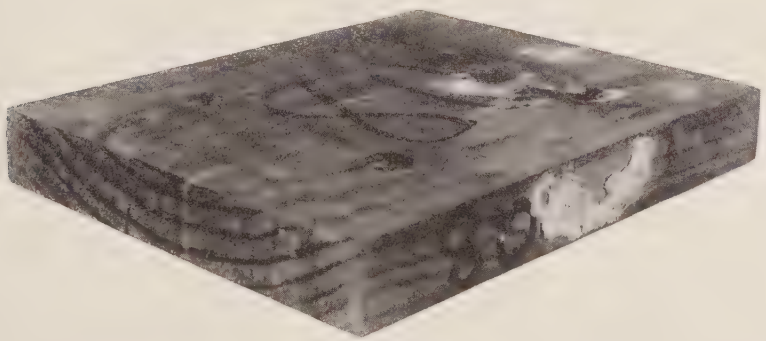

FIG. 8. Photograph of a large block which was given the hot and cold bath treatment with copper naphthenate. Note the large area on the top and edge of the block from which the green color has been removed. The mycelium of the wood-destroyer occupied the center of this region, surrounded by a zone of colorless wood. In the photograph, the white mycelium may be seen on the edge but it was brushed off accidentally from the top in handling. The fungus was undoubtedly the agency responsible for this decoloration.

decolored zone shown in Figure 8 and a sample of the adjacent green area were analyzed for copper. It was found that the former had 1.36 per cent of copper, and the latter, 1.56 per cent of copper. Southam and Ehrlich report that *Poria xantha*, the very species used in this test, decolors a zone just beyond the periphery of the mycelium. They interpret this to mean that the fungus causing the zone of decoloration does not grow in the presence of the toxicant, but changes it chemically—apparently to a nontoxic material—before advancing.

The comparative ineffectiveness of copper naphthenate in these tests involving incubation with *Poria xantha* led to the suspicion that this fungus is unusually tolerant of copper, and it was suggested that evidence on the question could be gathered by laboratory plating tests. Saturated solutions of cupric sulfate and cupric nitrate were made, and it was found in a preliminary test that *Poria xantha* and four other fungi used for comparison grew well on malt agars carrying these copper salts in the approximate dilutions of 1/1000 of the saturated solutions, *Poria xantha* not being at all retarded by dilutions of 1/100,000 and 1/1,000,000. With this information in hand, a second test involving higher concentrations was carried out and yielded the following striking result for cupric sulfate: On malt agar carrying the saturated solution in concentration of 1/50, the colony diameter of *Poria xantha* at seven days was 65.1 per cent of that on nontreated agar. In comparison with this the figure of *Poria microspora* was 57.6 per cent, while *Lenzites sepiaria*, *Lenzites trabea*, *Lentinus lepideus*, and *Polyporus versicolor* made no growth. On the agar with the solution at 1/500 dilution the comparable colony-diameter percentages for the six fungi, in the order named above, were: 99.5; 99.4; 44.5; 39.3; 32.2; and 51.4. This result is judged to be strongly indicative that *Poria xantha* and *Poria microspora* are much more tolerant of high concentrations of copper than are the other four wood-rot fungi used in the experiment.

Leaving these miscellaneous matters and directing attention to a consideration of what the test data show, it can be pointed out that the results support the belief gained from long experience that the hot and cold bath method is superior to the brush method of applying preservatives to wood, though scarcely as much as expected, and support the indications of the preliminary experiment that copper naphthenate is distinctly inferior to the chlorinated phenols and to phenyl mercury oleate in preventing decay by this particular fungus at the concentrations employed. Further, the 0.1 and 0.2 per cent dilutions of phenyl mercury oleate did not give satisfactory protection against decay, though 0.2 per cent was found by Verrall (35) at Saucier to protect well against natural infection of *Lenzites sepiaria*. The bearing of these results on repair procedures will be considered after a summary of previous work on these three preservatives has been presented. In passing it should be remarked that a glance at the decay ratings as-

signed to the inoculum blocks at the time of the original attachment, as set forth in Table 5, will reveal that the differences in results with the various preservatives and with the several methods are not due to the original differences in the inoculum blocks.

There have been very few investigations in which the fungicidal properties of all three of these toxicants on wood have been studied. Hunt, Baechler, and Blew (22) have given a general discussion of the status of the various wood preservatives as of 1942. While this paper is not a report on a specific research project, it is a valuable summary by some of the outstanding authorities in the field of wood preservation. Accordingly, it is interesting that Hunt et al. conclude that the toxicity of penta- and tetrachlorophenol appears to be from 10 to 100 times that of coal-tar creosote, depending upon the creosote and the toxicity values used for comparison. Even when diluted to 5 per cent concentrations, the toxicities of the chlorinated phenols appear to be equal to or greater than the toxicities of the coal-tar creosotes in common use. With reference to copper naphthenate, these authors state that its effectiveness has not received adequate study and no data are available as to the absorptions that should be injected for best results. They further comment on the fact that "the growing interest in the naphthenates as preservatives appears to arise from the increasing quantities of naphthenic acids being produced as byproducts of the petroleum industry and the urge to find markets for them. The fragmentary information available from various minor studies of copper naphthenate give favorable indications with regard to toxicity, permanence and field tests. Brush treatments with a naphthenate preservative are said to have given only mediocre protection but apparently satisfactory protection from substantial absorptions injected by pressure."

Hubert (21), in an outstanding paper, has made a comparative study of the decay-resisting and other properties of the chlorinated phenols, phenyl mercury oleate, and a number of other preservatives. Small wood blocks were treated with 5 per cent pentachlorophenol, 5 per cent of equal parts of tetrachlorophenol and pentachlorophenol, and 3 per cent phenyl mercury oleate and were then tested against *Lenzites trabea*, a common decay-causing fungus. On the basis of the weight lost, the pentachlorophenol and the phenyl mercury oleate were equal in performance while the mixture of the two chlorinated phenols followed closely. In the volatility and leaching tests, phenyl mercury oleate came out best, then pentachlorophenol, and finally the mixture. Considering all the various factors which must be pondered in selecting a preservative, including cost, Hubert assigns the following ratings to the preservatives:

Pentachlorophenol	96.3
Phenyl mercury oleate	94.5
Mixture of chlorinated phenols	90.0

The phenyl mercury oleate is marked down because of its high cost, its tendency to irritate the skin, and its weakness in resisting surface molds. It should also be indicated at this juncture that the phenyl mercury oleate used by Hubert was more concentrated than that employed in the present test.

A leaflet published by the New York State College of Forestry (4) gives a brief account of a comparative study of the effectiveness of several preservatives applied by brushing. The fungicides were added to mineral spirits in the following proportions: "2 and 4 per cent metallic content of zinc; 2 and 3 per cent metallic content of copper; 5 per cent chlorinated phenols; and 0.23 per cent phenyl mercury oleate." Small timbers were brushed with these preservatives and after they had been permitted to dry they were put in decay cellars where they were placed in contact with decaying wood. Several decay producing fungi were employed. It was concluded that "Under the specific conditions of these tests, the preservatives containing zinc naphthenate and copper naphthenate were the most effective in retarding decay, and even more so when they were combined with chlorinated phenols. The solutions containing only phenyl mercury oleate or only chlorinated phenols were less effective than those which contained only the naphthenates."

The next paper in this series will report on another investigation of wood decay conducted by the Industrial Test Laboratory and involving southern yellow pine sapwood, Douglas fir heartwood, and red oak heartwood. The three preservatives of Specification 52W5 (1) were applied by means of the 10-second dip and by the hot and cold bath methods. A total of 1260 panels were on test. One third of this number of panels were given a four months' tide-range exposure at Cape May after treatment with the preservatives, another third were given the same ocean exposure followed by fresh-water leaching, and the other third received neither the ocean exposure nor the leaching. Following the various procedures just outlined, inoculum blocks were attached to the panels and all the panels were then exposed in the humidity chamber for 6- to 12-month periods. Recently, all the panels were disassembled and inspected for the presence of decay. The following tentative conclusions can be made on the basis of the data obtained at this time:

1. The mixture of chlorinated phenols was definitely superior to phenyl mercury oleate and copper naphthenate in preventing decay by *Poria xantha*. This superiority of the chlorinated phenols was clear-cut with all three species of wood and with all types of exposure. The phenyl mercury oleate was no better than the copper naphthenate in this test.

2. The hot and cold bath method of applying preservatives was much superior to the 10-second dip method, which is comparable to a brush treatment.

A number of papers have been written on the subject of the use of these three toxicants as fungicides on fabrics. Furry, Robinson, and Humfield (15) have treated strips of cotton duck with these and other toxicants, inoculated and incubated them for 14 days with *Chaetomium globosum* Kunze, and then determined the breaking strengths. As a result, they conclude that 3 per cent o-phenyl-phenol, 2 per cent 2-chloro-o-phenylphenol, and 3 per cent pentachlorophenol are good mildew-resisting agents, although the first two are better than the last. Complete mildew protection was given by 28.5 per cent copper naphthenate and satisfactory protection was afforded by 0.8 per cent phenyl mercury oleate. It will be noted that as compared with the concentrations used in the present test, the percentage of phenyl mercury oleate was greater, the percentage of copper naphthenate much greater and the amount of the chlorinated phenols smaller. Goodavage (16), in a summary of observations made on treated cotton fabrics, states that copper naphthenate is so outstanding in its effectiveness to both rot and mildew that it is often used as the yardstick in evaluating the efficacy of other fungicides. Pentachlorophenol is dismissed as an irritant and as less permanent than copper naphthenate, while phenyl mercury oleate is stated to be an irritant and it supports surface molds. Bertolet (10) points out that sandbags containing 1 per cent copper, as a result of treatment with copper naphthenate, last 18 months to two years. For less drastic exposures, 0.5 per cent copper is considered adequate. Pentachlorophenol is said to be outstanding and low in cost. Shanor (32) has brought together all the information available up to January 1945 on fungus-proofing of textiles and cordage for use in tropical service. Copper naphthenate on fabrics which come in contact with soil has been found by the Corps of Engineers and the Quartermaster Corps to be superior to other preservatives now known. However, it is responsible for some tendering of tent and other fabrics. The chlorinated phenols are considered to be powerful fungicides, but limited in their use on fabrics because of lack of permanence due to water solubility and volatility. Field observations by the Corps of Engineers in Panama indicate that fabrics are adequately protected against mold by the use of pentachlorophenol. With respect to phenyl mercury oleate, it is pointed out that several fungi are mercury-tolerant to concentrations permitted in the treatment of fabrics.

Turning now to the papers in which only one of the three preservatives was studied, it can be said that as early as 1932, Hatfield (18), on the basis of tests involving 3 wood-destroying fungi and the agar-plate method, indicated that pentachlorophenol was a promising fungicide. In 1937, Bateman and Baechler (8) tested pentachlorophenol and tetrachlorophenol by the agar-plate method with the wood-rotting fungus, Madison 517. They concluded that of the 40 compounds tested, these two toxicants were the cheapest source of effective toxic action. As a result, they recommended service tests. Further research was reported by Carswell and

Nason (14), and by Carswell and Hatfield (13), in which 5 per cent pentachlorophenol in a petroleum solvent was shown to have excellent fungicidal properties against 12 wood-destroying fungi and 12 other fungi when tested by the standard agar-plate method. Field exposures extending over three seasons are described involving saplings and fence posts. Two carloads of lumber were placed in service tests for two years. Inspection of all this treated stock revealed that pentachlorophenol was exceedingly effective for controlling decay and termites in all cases where at least 0.5 pounds of toxicant per cubic foot of wood was applied. Richards (28) has described an exposure test in which 2″ by 4″ by 6′ southern pine was pressure-treated with pentachlorophenol and then exposed in the soil at Almirante, Panama, for 3 years. At the end of that time, none of the pieces were damaged by decay. In another service test, Blew (11) describes the exposure of 198 fence posts in the soil at the Harrison Experimental Forest, Saucier, Mississippi. Half of this number were pressure-treated with 4.82 per cent pentachlorophenol in crank case oil, giving an average absorption of 6.7 pounds per cubic foot, and the other half were treated with 3.02 per cent pentachlorophenol, giving an absorption of 6.4 pounds per cubic foot. After eight years of exposure, only 5 of the treated posts are decaying, while all the untreated posts have been attacked by decay and termites. Hunt and Snyder (23) have made a progress report on a soil exposure test at Barro Colorado Island, Canal Zone. Some of the stakes in this test were treated with a mixture of 3 per cent pentachlorophenol and 2 per cent chloroorthophenylphenol in mineral spirits to which a water-repellent had been added. After four years, the panels given a 3-minute dip, achieving an absorption of 0.8 pound per cubic foot, have all been destroyed by termites but only one showed decay in this period. The panels which were given an 18-hour soak, yielding an absorption of 3.4 pounds per cubic foot, show no decay, and 80 per cent of the panels have been destroyed by termites. Hatfield (19) has summarized the information on pentachlorophenol available up to 1944. A number of service tests are described, among them being one involving the treatment of some 4″ by 4″ timbers installed by the Mississippi Highway Commission. After five years of exposure, all specimens are in perfect condition. Further, 200 southern yellow pine railway ties were treated with 4.9 per cent pentachlorophenol. One-half of these ties had an average absorption of 5.58 pounds per cubic foot and the other half, 7.1 pounds per cubic foot. One set was laid in Texas in 1928 and the other in 1939. At the 1943 inspection, all of the ties were in track and in good condition. Hatfield points out that "the fact that (pentachlorophenol) is a single chemical compound and contains a specific preservative value per unit weight means that its constancy of performance can be predicted and assured."[6]

[6] On the other hand, it could be argued that there is a greater possibility that some fungus will be resistant to a single compound than to a mixture.

The writers know of no references, other than those already considered, in which there are described tests of the decay-resistance offered wood by phenyl mercury oleate. In the case of copper naphthenate, the situation is nearly the same. Bartlett (7) has described tests of copper naphthenate (with slightly more than 2 per cent copper) on wood. However, this work is of little value since wood-destroying fungi were not employed in the test, merely the cellulose destroyers *Trichoderma* and *Chaetomium*. Bartlett does give a summary of the preliminary report by Berry and Cater (9) in which 20 pieces of Laylay wood (*Corida lockhartii*) were treated with 15 per cent copper naphthenate by the hot and cold bath method, achieving by this means an absorption of 9 pounds per cubic foot. The stakes were placed in the ground in a timber graveyard in Trinidad. After 20 months all of the untreated stakes were destroyed by fungi and termites, while all of the treated pieces were perfectly sound. Similar results were obtained upon treating and exposing 110 pieces of white pine for a year and a half.

A number of studies have been made of the fungicidal properties of copper naphthenate on fabrics. One of these is related in the paper by Marsh et al. (25). Copper naphthenate containing 8 per cent copper was used to treat duck, with the result that this material took up from 0.05 to 0.8 per cent copper. It was found that cotton duck with 0.4 per cent copper exposed to soil-burial for 9 days lost only 1 to 16 per cent of its breaking strength, while duck with 0.8 per cent showed a reduction of 0 to 3 per cent. Copper naphthenate was more effective than copper oleate, copper "tallate," or copper hydrogenated resinate. It was suggested that copper naphthenate is superior to the others because in addition to the copper, the naphthenic acid is also toxic to fungi. It was also indicated that the effectiveness of the copper naphthenate varied with the geographical origin of the naphthenic acids. Attention was directed to the fact that copper is lost from the fabric in the vicinity of the fungi, although this phenomenon is less marked in copper naphthenate than in the other copper soaps studied. The OSRD Manual of Fungi and Tropical Deterioration (36) states that tent ducks are adequately protected when treated with copper naphthenate in which there is a minimum of 0.8 per cent copper, while 0.3 per cent is satisfactory for tarpaulins. Marsh *et al.* (26) point out that copper treated fabrics containing as much as 0.8 per cent may show considerable breakdown because of the presence of copper-tolerant cellulose-decomposing fungi in the soil. This may explain why fabrics treated with copper naphthenate and then tested by pure cultures of *Chaetomium* and *Metarrhizium* often give higher values for breaking strength than those fabrics tested by the soil-burial procedure.

To epitomize this lengthy account of the previous work on these three preservatives, it can be said that the chlorinated phenols have been investigated much more thoroughly in wood than the other two toxicants,

having been subjected to extensive service tests of considerable duration as well as the usual laboratory and outside exposure tests. Thus there is an accumulation of data which indicates that the chlorinated phenols, especially pentachlorophenol, are superior fungicides. On the other hand, there are surprisingly few studies in which the effectiveness of copper naphthenate in preventing decay of wood has been investigated, although a number of papers have appeared on the use of copper naphthenate on fabrics. Papers on phenyl mercury oleate are even scarcer.

Returning now to the original object of this test which was to determine the effectiveness of the three wood preservatives in preventing the spread of decay from infected to sound ship timbers, it will be recalled that four possible repair procedures were outlined in the Introduction to this report. These possibilities will now be considered in the light of the data obtained in this investigation as well as in the light of the data accumulated as a result of other studies. It is apparent that the first thing to do in repairing a vessel with decay damage, is to remove all the obviously rotting wood. The timbers which surround the decaying areas should have the paint removed from them and should then be thoroughly swabbed with a clean paintable preservative. Of these, the test results available to date favor the chlorinated phenols. The new, replacing wood should either be swabbed or else given the hot and cold bath treatment with the same preservative. The latter procedure is more desirable, but considerations of time and equipment may force the swabbing application. On the basis of the test results, it can be said that the mere brushing of the old timbers on a boat possessing decaying wood, without the accompanying treatment of the new wood, appears to hinder spread of the decay from the infected to the sound timbers, but is not in itself adequate without treatment of the replacement members.

An Industrial Test Laboratory report (5, 6) has shown that chlorinated phenol and phenyl mercury oleate preservatives are valueless against marine borers, while copper naphthenate preservative gives some protection. It is accordingly the practice to specify (1, 2, 3) the use of copper naphthenate preservative (or creosote) on outer planking below the heavy load water-line and to permit the use of the chlorinated phenols elsewhere. This practice should be continued, and in repairing a boat with decay, all replacement wood except the outer under-water planking should be treated with the chlorinated phenol preservative.

Several other repair suggestions are pertinent at this point. In removing the old decaying timbers on a vessel, it is advisable to remove the wood to a point one or two feet beyond the infected area, for it must be emphasized that the very earliest stages of decay are difficult to recognize, especially by untrained personnel. Further, the fact that decay developed, indicates that there must have been a water source, a leaking seam, or something similar.

This point of leakage should be located and the condition corrected. Often the conditions leading to decay indicate poor ventilation. Air circulation should accordingly be improved. In selecting timbers to replace the decayed members, it would be advisable to use seasoned lumber and to employ heartwood of such moderately durable timbers as dense Douglas fir, white oak, and dense southern yellow pine. More than the usual care should be exercised in the selection of these timbers for they are going to be placed in a potentially dangerous place—a place where they may be in contact with decaying wood.

With respect to new construction, the data obtained in this project and those from other sources reviewed herein indicate that all wooden vessels should be treated with a preservative and that the chlorinated phenols are most likely to prevent serious decay damage. However, since it has been shown (5, 6) that the chlorinated phenols are ineffective against marine borers, the most logical procedure would appear to be to treat the outer wooden planking below the heavy load water-line with copper naphthenate (or creosote or Celcure) to discourage the borers, and to treat all other parts with chlorinated phenols.[7] Of course for the sake of simplicity, it would be desirable to treat all of the boat with one preservative, but unfortunately a single, generally acceptable material has not been found which does an effective job against both marine borers and the decay organisms tested. On the present available evidence the choice is between simplicity in preservation procedure with its resulting decay damage, or the use of two preservatives for successful control of both borers and fungi. Very much to the point is the fact that this division of the ship into two treating areas is recognized and sanctioned by the Bureau of Ships preservative specification (1) and by the Bureau of Ships general specifications (3). The use of a special antifouling paint on the lower part of the hull of ships, distinct from the top side paint is another case of the recognition of this principle. In view of all these considerations, it is recommended that copper naphthenate preservative (or creosote or Celcure) be used on outer hull wood planking below the heavy load water-line, and that the chlorinated phenols be used on all other parts of wooden ships which should receive preservative treatment.

SUMMARY

In the repairing of wooden craft, it is the practice to replace the obviously decaying timbers with new lumber which is either untreated or treated with a wood preservative, while the old, remaining wood may or may not be treated with a preservative. The question arises as to the

[7] Another possibility would be to use mixtures (as advocated by Verrall (34)) of chlorinated phenols with the copper-containing preservatives. More experimental work is needed on this before it can be recommended, however.

effectiveness of these various repair procedures, and of the several preservatives, in preventing the spread of decay from infected timbers to sound ship timbers. The present investigation attempts to explore this question.

Southern yellow pine test panels, each consisting of three blocks, were employed in the investigation. One of these blocks was first infected throughout with a wood-decaying fungus, and thus was equivalent to a decaying timber and was used as an inoculum block. Several sets of these panels were treated with copper naphthenate, chlorinated phenols, or phenyl mercury oleate. For each of these three preservatives, one set of panels was prepared in which the inoculum blocks were brushed with one preservative and the other two blocks were given the hot and cold bath treatment in the preservative; in a second set all the blocks were brushed with the preservative; in a third set only the inoculum blocks were brushed with the preservative; and finally a fourth set was left untreated throughout. The treated and assembled panels were exposed in a humidity chamber for a year and a half, at the end of which time the panels were disassembled and observations were made on the blocks for the presence of decay.

The following conclusions may be formulated on the basis of the results obtained in this investigation:

1. The chlorinated phenols and phenyl mercury oleate (at 0.5 per cent concentration) were definitely superior to copper naphthenate in preventing the spread of decay by *Poria xantha* from infected to sound wood.

2. Solutions containing 0.1 per cent and 0.2 per cent of phenyl mercury oleate were not effective against decay by this fungus.

3. The protection against decay offered by the hot and cold bath method of applying wood preservatives was superior to the protection achieved by the one-coat brush method.

4. The different treating combinations used in this study in applying the preservatives may be arranged in the following order of probable effectiveness against decay:

a. Treatment of wood used in making replacements with the hot and cold bath method and brushing the adjacent old timbers with the preservatives.

b. Hot and cold bath for the replacements but no treatment of adjacent old timbers.

c. Brushing all wood with the preservatives.

d. Brushing the old wood with the preservative and using untreated wood in making replacements.

e. Leaving all the wood untreated.

It is recommended that in repairing ships possessing decaying timbers, the following steps be taken:

1. The removal of the obviously rotting timbers and, in addition, all wood to a point one or two feet beyond the visibly infected area. (In the case of planking, this would mean the complete removal of all planks showing any decay and the removal of the planks above and below the decayed members, and of the end of the adjacent plank in the same strake.)

2. The removal of the paint from all of the surrounding wood to a distance of several feet and the swabbing of this remaining wood with a preservative such as the chlorinated phenols.

3. The use of the heartwood of those timbers which have considerable natural decay-resistance, such as dense Douglas fir, dense southern yellow pine, and white oak, in the replacement of the decayed wood.

4. The treatment of the new and preferably seasoned replacing timbers with a preservative such as the chlorinated phenols, by either swabbing or by the hot and cold bath method.

5. The location of the source of the water which contributed to the development of the decay, and the elimination of this water source.

It is further recommended that in the construction of wooden ships one of the preservatives known to be relatively effective against marine borers (such as copper naphthenate, creosote, and Celcure) be applied to the outer planking below the heavy load water-line, and that a preservative, such as the chlorinated phenols, be employed on all other parts of the vessels which should receive preservative treatment.

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